# Prospects for the production of fuel from microalgae in Ukraine

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**Abstract.** Today, about 90% of the world's energy consumption is a consequence of burning fossil fuels, which leads to a rapidly decreasing reserves and the need for new types of fuels. The article is devoted to the topic of fuel production based on biomass of microalgae in Ukraine using the existing capacities of enterprises. Using a SWOT analysis, the paper discusses in detail the methods of growing, collecting and processing microalga biomass for fuel production. So, given the geographical position of Ukraine and the possibility of using waste from other industries, it allows the use of closed-type systems. Despite their initially high cost, they are more efficient than open systems. After the cultivation process, the moment comes to collect the biomass with the highest oil yield, which is an important factor for the energy efficiency of such production. Flotation and flocculation are most suitable for large-scale production, while sedimentation, filtration and centrifugation are more suitable for laboratory research. Among the processing methods, we single out three areas - these are thermochemical and biochemical conversion of biomass, as well as chemical transformations. Using the technological capacities of such enterprises in Ukraine there is an excellent opportunity for this production. One of the impediments to the introduction of such production is the lack of a unified research program in this area. Further research is aimed at practical studies of biofuel production by laboratory methods and analysis of its performance properties.

## 1. Introduction

Today, about 90% of the world's energy consumption is due to the burning of fossil fuels. This is primarily due to its dominant operation in the transport sector, which accounts for about 58% of total fossil fuel use [1]. In addition, the exhaustive consumption of fossil fuels has adverse effects, namely on health and environmental problems. In particular, there is an imminent threat of global warming due to extreme emissions of greenhouse gases (GHGs), environmental pollutants and devastation of habitats of ores, flora and fauna due to oil exploration.

The term "biofuel" refers to fuel that is formed directly or indirectly from biomass. Biomass is considered biological materials that are energy crops, waste and by-products of agriculture, wood processing waste, manure or solid waste.

By type of raw material, biofuels are divided into three generations. In search of viable and cost-effective alternatives to fossil fuels, scientists have reported the remarkable properties of biomass produced by algae to produce an improved version: third-generation biofuels. In their research, scientists have shown that algae have the ability to produce crude oil, which can then be easily processed to produce diesel fuel and gasoline. Specific types of algae that can be classified as microalgae or microalgae can also be genetically modified to promote the production of fuels such as bioethanol. While macro plants such as red and brown algae typically include seaweed from marine areas, it is mainly blue-green algae microalgae such as dinoflagellates and diatoms. It is believed that compared to other raw materials, seaweed has a high content of cellulose-lignin. Carneiro M. L. [2] and other scientists have identified the advantages of third-generation fuel production over the first, which include efficient land use and the ability to prevent competition with food crops in the case of third-generation biofuels.

Algae have the ability to produce more energy per acre of land compared to other crops such as sugar cane, wheat and corn. It is for these reasons that microalgae are biomass with maximum potential, which can be a substitute for transport diesel fuel without adversely affecting food and other crop products. The latest achievement in biofuel production is "4th generation" biofuel. In the production of this raw material, special living microorganisms are used, which with the help of photosynthetic cells will be able to produce biofuel raw materials for some time (more precisely - several cycles of photosynthesis). Microorganisms will use carbon dioxide to ensure their viability.

The possibility of using algae for fuel production, according to some authors, is determined by their high content of lipids. So Vorobyov V. [3] in his work, notes that the composition of the lipids of algae and lipids of oilseeds are similar to each other, and contain polyunsaturated fatty acids. In addition, they also indicate that the content of fatty acids in microalgae living in natural conditions is about 40% of the total mass, while in cultivation conditions can reach 80%.

Microalgae can duplicate their biomass during the day and are able to reach a full growth cycle in a few days, which is why they are considered 10-20 times more productive than typical crops for biofuel production, such as soybeans or sugar cane [4].

You should pay attention to the content of lipids per unit weight of dry biomass of microalgae, because it can vary for different species. To select an efficient species of microalgae for biofuel production, the volumetric productivity of this species is taken into account.

Given all the advantages of microalgae, their unpretentiousness to the place of cultivation, high content of lipids, the question of maintaining optimal conditions for their growth remains relevant. This is due to the fact that algae are sensitive to changes in water temperature, which is why it is necessary to ensure a constant temperature during the day (sharp daily fluctuations are unacceptable). These aspects make scientists think about creating the necessary conditions for the continuous cultivation of microalgae on an industrial scale. For example, the US Department of Energy has studied algae with a high oil content. The researchers concluded that California, Hawaii and New Mexico are suitable for industrial production of algae in open ponds. For 6 years, algae were grown in ponds with an area of 1000 square meters. meters. The yield was more than 50 grams of algae per 1 square meter per day.

Chevron Corporation, one of the world's energy giants, has begun research into the possibility of using algae as an energy source for transportation, particularly for jets. Honeywell, UOP recently launched a project to produce military jet fuel from algae and vegetable oils [5]. Green Star Products has completed the second phase of testing of a demonstration plant for the production of biodiesel from algae. During the second phase, the optimal conditions for growing algae were selected [6].

Japan's large energy company Tokyo Gas Co intends to build a demonstration plant that will generate electricity from seaweed. Methane emitted from finely chopped algae will be used for the operation of gas generators at the station. For a number of Japanese prefectures, coastal pollution by algae remains a serious environmental problem. They often emit a foul odor when rotting and spoil the landscape. Meanwhile, the latest development of Japanese experts proposes to solve this problem with economic benefits [7].

As for the experience of European countries, it also has its achievements, namely the European Algae Biomass Association (EBA) is a European association representing both research and industry in the field of algae technology. Association with headquarters in Florence, Italy. Its overall goal is to promote mutual exchange and cooperation in the production and use of biomass, including the use of biofuels and all other wastes. It aims to establish, develop and maintain solidarity and ties between its members and to protect their interests at European and international level.

Ukraine plans to produce biofuels using a special type of algae. The European Commission for the Algae Project is funded by the Seventh Framework Program, consists of three algae biofuel projects, and aims to design and build various biofuel centers that will cover 10 hectares of land. BIOFAT, All-Gas and InteSusAl projects.

Because different fuels and chemicals can be derived from seaweed, it has been proposed to study in detail the feasibility of different production processes (conventional extraction / separation, hydrothermal liquefaction, gasification and pyrolysis) for use in the integrated algae program Biorefinery [8].

According to the State Targeted Economic Program for Energy Efficiency and Development of Energy Production from Renewable Energy Sources and Alternative Fuels for 2010-2020, the search for and implementation of algae biomass processing technologies is a promising and cost-effective direction [9].

It should also be noted that it is possible to use as raw materials not only artificially cultivated microalgae in open / closed systems, but also microalgae from natural ponds and lakes.

On average, 140 g of dry mass of microalgae is required for the production of 1 liter of biofuel by transesterification. Usually this amount will vary depending on the type of microalgae and the desired finished product.

Algae released by the storm on the Black and Azov Seas may also be suitable for biofuel production, but in this case it is necessary to take into account the fact that such algae have a high salt content, which may affect the number of stages of algal biomass processing and the amount of finished product.

## 2. Materials and Methods

The object of work is the production of hydrocarbon fuels based on microalgae. The following methods were used in the preparation of the scientific work: analysis of the literature on the selected problem (methods and features of cultivation and cultivation of microalgae, technologies of algae biomass processing with subsequent production of biofuels); comparison of biofuel production technologies based on microalgae; SWOT-analysis of third generation biofuel production; generalization of research results. Together, they provide an opportunity to assess in more detail the situation regarding implementation in Ukraine. Accordingly, the search for solutions becomes more specific.

## 3. Results

Today, the cultivation of microalgae biomass in open systems is not a promising direction for Ukraine, as the geographical location and climatic conditions are not favorable for growth in open systems. While the use of bioreactors will not only allow to obtain a higher yield of biomass during cultivation, but also to use as a nutrient medium the waste of other enterprises.

Existing financing programs for alternative energy [10] make it possible to develop a program for the cultivation and processing of biomass of microalgae in Ukraine and implement it at existing analogues. Among such enterprises are the State Enterprise UKRSPIRT, the largest producer of high-quality alcohol and alcohol-containing products in Ukraine. It is possible to produce bioethanol from microalgae at the facilities of this enterprise. Limited Liability Company "BIODISK", which previously planned to organize the production of synthesis gas, which is true of household waste and other materials that accumulate in municipal landfills.

Among the prospects for the introduction of third-generation biofuel production in Ukraine is also the possibility of combining biofuels with existing, traditional, fuels, which will reduce the use of fossil fuels. In addition, the use of such biofuels in the transport or energy sectors will reduce Ukraine's import dependence when purchasing fuel from foreign producers.

When reviewing and implementing any new technology for the production of certain products, it is necessary to clearly assess the opportunities and problems that may arise during its implementation.

As mentioned earlier, for optimal and rapid growth of microalgae, it is necessary to ensure a constant temperature, access to solar energy, water and carbon dioxide contained in the air. That is why to ensure efficient production it is necessary to determine. The optimal systems for cultivation, as well as collection methods and technologies for processing algae biomass.

Given the geographical position of Ukraine, namely the location in the temperate climate zone, this affects the significant seasonal amplitudes of air temperature, especially in the south and east. Winters in western Ukraine are noticeably milder than in the east. In summer, on the other hand, higher average temperatures are observed in the east than in the west. The average annual temperature ranges from +5.5 - +7 ° C in the north to + 11 ° - +13 ° C in the south. The average temperature in January, the coldest month, ranges from −3 ° C in the southwest to −8 ° C in the northeast. The average temperature in July, the warmest month, ranges from +23 ° C in the southeast to +18 ° C in the northwest. These data make it impossible to cultivate microalgae in open water bodies within Ukraine, because cultivation in this case will not be profitable (Figure 1).

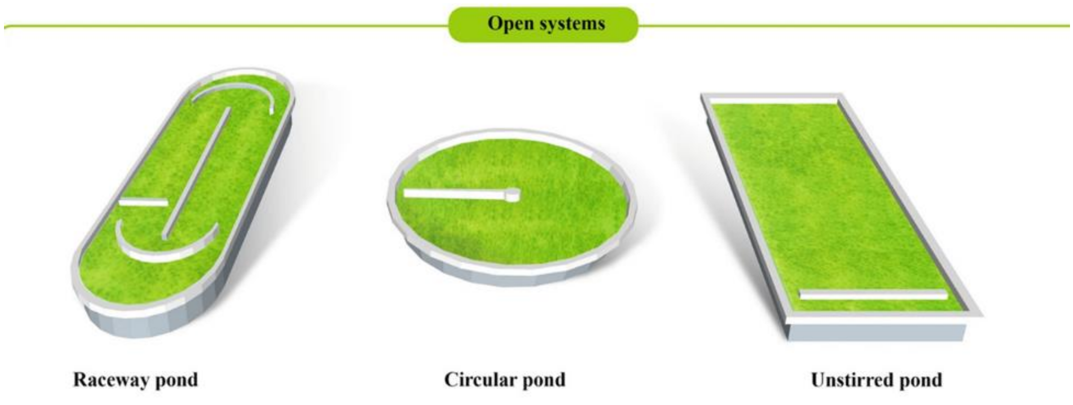


**Figure 1.** Open type systems for cultivation of microalgae Source: https://www.researchgate.net/figure/Examples-of-different-types-of-pond-systems-for-outdoor-microalgae-cultivation_fig4_333312797

Growing microalgae in closed systems, so-called photobioreactors is more attractive for the Ukrainian climate, and makes it possible to use waste from other enterprises (Figure 2).

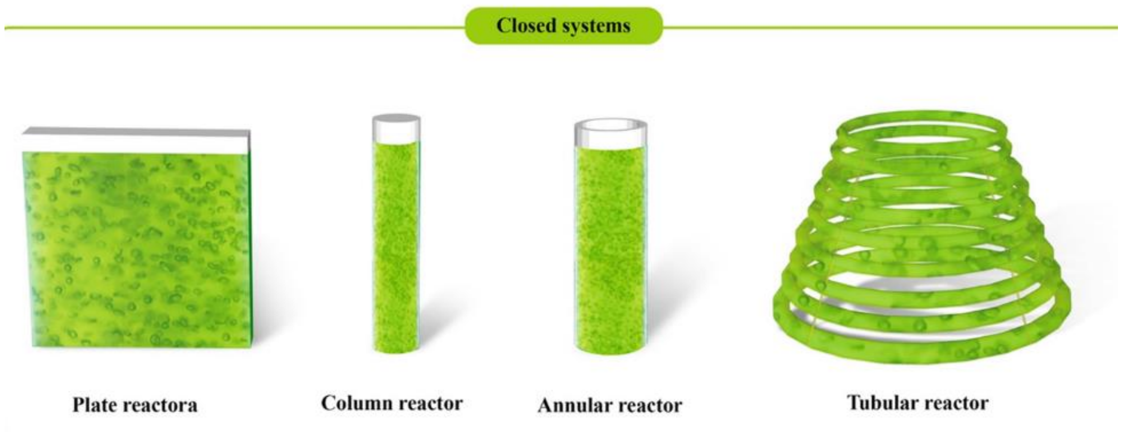


**Figure 2**. Closed type systems for cultivation of microalgae Source: https://www.researchgate.net/figure/Examples-of-different-types-of-pond-systems-for-outdoor-microalgae-cultivation_fig4_333312797

For example, it is known that the cultivation of microalgae occurs with the provision of a special nutrient medium. Therefore, in order to reduce the cost of the resulting biomass for the preparation of nutrient media, it is possible to use mineral fertilizers. The use of wastewater from some enterprises, in particular sugar and hydrolysis plants, will be a cost-effective solution. Photobioreactors can be of both stationary and suspended types, which will save production space in the early stages of development, but in the future there will be questions about the feasibility of using certain, and this may be related to reliability, safety and overall performance.

After the process of cultivation and cultivation of algae biomass, the question of collecting biomass with maximum oil yield arises. It also has its nuances, depending on the type, size of microalgae and the desired volume of oil at the outlet.

Sedimentation, filtration and centrifugation are simple and fast methods of separating oil from total biomass. They are ideal for laboratory practice during development and research, but are not effective for large-scale production.

Sedimentation cannot be used for microalgae species that may be small in size, centrifugation is not suitable for large-scale production, but is characterized by ease of installation and ease of management. Then for microalgae with large sizes, you can apply filtration, but the disadvantage of this method is the long processing time.

If we talk about large-scale production of biofuels based on microalgae in Ukraine, the most optimal are flocculation and flotation. Despite the high cost of flocculants, they are effective for large-scale production and give a high oil yield, which is an important component for determining the profitability and cost of finished products.

The choice of production technology directly depends on the desired end product, financial and technological capabilities of the enterprise.

Among the existing methods of processing algae biomass will be: thermochemical and biochemical conversion and methods of chemical transformation.

Anaerobic fermentation and fermentation are typical methods of biochemical conversion of algal biomass. In Ukraine, it is realistic to implement both methods of processing using existing equipment at similar plants (Figure 3).

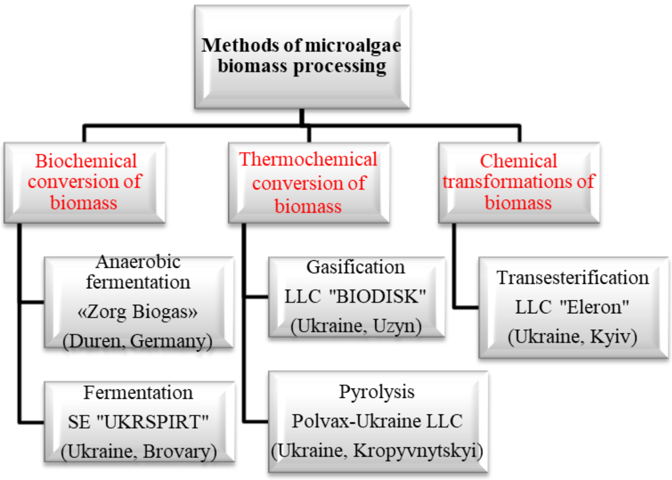


**Figure 3.** Methods of microalgae biomass processing in Ukraine

For example, the company "Zorg Biogas" built the largest biogas plant with a capacity of 7.5 MW at the sugar plant using the new technology. This makes it possible together with Zorg Biogas to establish and implement the production of biomethane from biomass of microalgae [11].

The state enterprise UKRSPIRT is the largest producer of high-quality alcohol and alcohol-containing products in Ukraine. The application of algae fermentation technology at UKRSPIRT will allow to produce high-quality bioethanol [12].

The main thermochemical methods of algal biomass conversion include gasification, pyrolysis, hydrothermal liquefaction (HTL).

The process of gasification is achieved by the reaction of biomass of microalgae in the gasifier in the absence of any form of combustion of air, oxygen or steam. Using this method, you can get synthesis gas. The gas yield and its composition will also directly depend on the composition of the raw material. The yield can be adjusted by changing the process parameters (pressure, temperature) and adding catalysts.

It is possible to sell such production in Ukraine at BIODISK LLC (Fig. 3.4.), Which previously planned to organize the production of synthesis gas, which is true from household waste and other materials that accumulate in municipal landfills [13].

Another variant of thermochemical conversion is pyrolysis, which takes place in the absence of oxygen or air, usually at atmospheric pressure in the temperature range of 400-600 ° C for conventional pyrolysis, up to 800 ° C for microwave pyrolysis and at least up to 300 ° C for catalytic pyrolysis.

Pyrolysis, in contrast to gasification, has its drawbacks, namely the need for preliminary preparation of raw materials. Therefore, the use of pyrolysis is possible only in enterprises where the provision of pre-drying of raw materials. It is possible to introduce the production of bio-oil from algae raw materials in Ukraine at Polvax-Ukraine LLC [14].

The most popular method of converting biomass to fuel is the transesterification process, which has recently attracted much attention as a method of producing biodiesel, but its economic feasibility is still limited due to the high cost of enzymes.

Eleron LLC offers for sale a complete technological line for biodiesel production [15].

## 3. Discussion

A literature review of the world experience of using microalgae biomass as a raw material for third-generation biofuels showed that microalgae easily adapt to different cultivation conditions, and their biochemical composition satisfies the production of biofuels on a large scale. According to the literature review, a SWOT analysis of the use of microalgae biomass for the production of hydrocarbon fuels in the world was conducted.

Based on the requirements for the cultivation of microalgae, it was found that for the climatic zone of Ukraine will be effective to use closed-type systems - photobioreactors. This will provide a higher yield of biomass than when using open cultivation systems, as well as the use of sugar production waste in technological processes.

It is proposed to use flotation and flocculation as the most effective methods as biomass collection methods. The main technologies of biomass processing are considered and perspective technologies for biofuel production in Ukraine are singled out.

## Conclusions

A detailed SWOT analysis of the production of third generation biofuels for Ukraine was conducted, which made it possible to clearly identify the main strengths and weaknesses, as well as the threats and opportunities for the introduction of such production.

In the course of the work, the main options and recommendations for the introduction of biofuel production based on microalgae were analyzed and identified.

Further work aims to expand the scope of analysis of biofuel-based biofuel production, namely to analyze in more detail the threats and opportunities associated with the introduction of microalgae production in Ukraine.

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