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ASSESSMENT OF BIOFUEL PRODUCTION TECHNOLOGIES FROM MICROALGAE AND ORGANIC WASTE

Introduction

Today, the processing of organic matter, such as organic waste or microalgae, is an important way to renewable energy sources. To maintain a prosperous life of the population, it is critical that renewable sources of energy be found. While it is important for energy to be produced without harmful emissions and long-term damage to the environment, it is equally important for the form of energy to be reproducible over extended periods. Biofuels are a form of renewable energy by the fact that they are generated in shorter cycles, as compared to the geological processes required to generate fossil fuels [1].

Problem statement

Because mineral and organic energy reserves in the near future will no longer meet the ever-greater and greater energy needs of mankind. New technologies are already emerging around the world that allow the production of organic biofuels based on many plant species and waste. However, the cultivation of crops, on the basis of which in the future will produce biofuels, leads to depletion of land resources. Simply put, the thin layer of fertile humus as well as the top layer of humus is gradually depleted, which can lead to the decommissioning of millions and billions of hectares of arable land.Thus, the development of technologies that involve expanding the raw material base for biofuel production becomes obvious [2].

Analysis of previous research

A decade ago, the green technology space was alight with the energy potential of algae. Fuel derived from algae, dubbed the 'third-generation biofuel', holds several key advantages over earlier feedstocks based on plant crops such as sugar cane and corn (the first generation of biofuel production) and vegetable or animal waste streams (the second). These algal advantages include higher biofuel yields compared to previous systems, a diverse list of possible fuel types including biodiesel, butanol, ethanol and even jet fuel, as well as the fact that large-scale algae cultivation — whether in open ponds or more advanced closed-loop systems — can be done on land unsuitable for food crops, removing a key concern that biofuel feedstock crops would compete with food producers.One more advantage of algae can be considered that they, unlike the cultivation of other plant materials, do not need fertilizing. For their full growth, algae use only carbon dioxide (CO_2). Moreover, the higher the concentration of carbon dioxide, the faster the algae will gain weight [3].

Algae biodiesel is the third generation of biofuels obtained by processing plant raw materials. Vegetable fat is extracted from algae, which will be used to produce biodiesel [4]. Algae are universal because they do not have a true root system or leaves. They do not contain cellulose or lignin, which improves the process of converting raw materials into biofuels [5]. For greater clarity, we can show quantitative comparative characteristics of the fat content in terrestrial plants and their aquatic relatives. In the Table 1 an amount of liquid fuel obtained from different raw materials is presented.

Table 1

Amount of liquid fuel obtained from 0.4 ha of occupied area[6]

Raw material	Liquid fuel, L
Corn	68.4
Soy	181.7
Sunflower	408.8
Algae (natural conditions)	700.3
Algae (laboratory parameters)	56 781.0

It is also equally important that algae require 99 % less water in a closed system than other terrestrial crops. Due to the fact that aquatic plants do not have a strong stem and roots and accumulate nutrients over their entire surface, they are able to gain biomass much faster than other crops [6].

In the last 5 years, crop oil has become more expensive due to rising fertilizer prices, as well as their later transportation. Here again, algae are an alternative, as the production of algae oils using low-cost waste is a very attractive alternative to next-generation biofuels. Also, the use of seaweed oil, instead of that obtained from food crops, does not compete with food and does not affect food prices.

But, despite the great prospects of bioenergy from algae, their cultivation is also not a cheap pleasure. For example, if we take into account the heterotrophic cultivation of algae. Heterotrophic cultivation is based on the use of sugar as a carbon source and leads to a much higher oil content compared to those grown under phototrophic conditions. But this technology is expensive and competes with the food market, which complicates the economically successful application of the method.

We propose to consider in more detail the approaches to the implementation of this type of bioenergy. As is already known, there are certain varieties of algae that contain a significant amount of vegetable fats, from which in the future you can make the same biodiesel. It is not surprising that in order to obtain biofuels from algae, they need to be grown, but for this you do not need to occupy the sown area of the land fund. Lower plants can grow in ponds, on the seabed or in specially arranged bays, ie algae occupy those areas that are not involved in food production. That is why we can say that the third generation of biofuels is still in the development stages, but it is already clear that this bioenergy has the greatest prospects [7].

The main problems that arise during the cultivation of algae in open water is excessive sensitivity to temperature fluctuations. To overcome this problem, scientists have begun to practice the technology of growing algae in small bioreactors.Moreover, in bioreactors located near thermal or nuclear power plants. Thus, the waste heat of power plants will be able to cover up to 77 % of the algae's heat needs. Thus, this technology will not require a hot desert climate, but on the contrary allows you to get biodiesel from algae in any part of the planet. Bioreactors can solve most of the problems faced by algae grown in open water. But on the other hand, bioreactors require significant financial investment [8].

Algae are unpretentious and easy to grow and feel good in mineral-poor environments. Their growth requires only the presence of sunlight, carbon dioxide and nitrogen, but the amount of nitrogen required is much less than that of algae for agricultural plants.

Among the approaches to the implementation of this type of bioenergy, there are two types of conditions:

1. Phototrophic conditions (presence of light and carbon dioxide as a carbon medium);
2. Heterotrophic conditions (lack of light, the presence of glucose as a carbon source and the presence of organic molecules as raw materials).

At the same time, phototrophic conditions will not only be cheaper, but will help solve greenhouse gas problems. Whereas heterotrophic conditions require significant investment, as sugar is a competitive product on the market [9].

Research methodology

The study was based on the analysis of theoretical studies and comparison of different types of terrestrial biofuels with microalgae and oganic waste, at the economic, environmental and social levels with calculations.

Results and discussion

Let's start with history, countries such as Japan, Israel, France, the United States and Germany became interested in algae biofuels for the first time in the 1970s during the oil crisis. But as soon as the crisis receded, alternative energy from algae was forgotten. But the coming second wave of the disappearance of mineral energy reserves, forced to restore the energy of the 70's [10].

At this stage, Sustainable Green Technologies (SGT) is developing new technologies related to the extraction of oils and algae (Fig. 1). They focused on processes that will produce high amounts of biomass and on a steady increase in the percentage of algae oils.

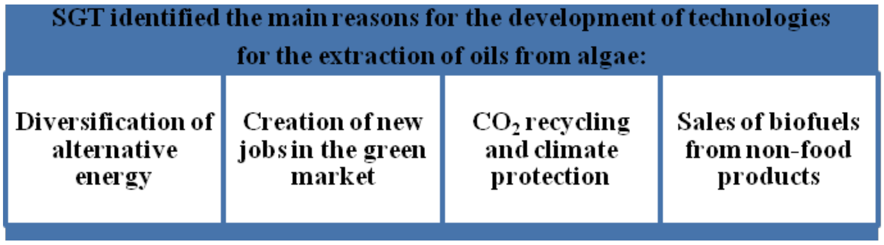

Fig. 1. Scheme of the main causes of the technology of extraction of oils from algae according to Sustainable Green Technologies (SGT) [11]

So, while you do not have to pay for sunlight and it is more than enough for alternative energy, it compensates about 80 % of the total for this technology. The rest of the amount falls on the conditions of growing algae [12].

Scientists from European countries have proven that the energy potential of algae is much more efficient than the potential of oilseeds (including rapeseed and sunflower). Thus, the energy potential of algae is 50–100 times greater than the potential of crops. In addition, algae grow 20 to 30 times faster than terrestrial plants and require only sunlight, temperature maintenance and carbon to grow. This is why the cost of growing algae is much lower than the cost of growing oilseeds, especially considering that bioreactors can be built near power plants, thus reducing the investment in finding heat to grow algae. Moreover, if bioreactors are installed near thermal power plants or nuclear power plants, it is possible to save society from CO_2 emissions.

Thus, the development of algae bioenergy is cost-effective and investment-attractive, contributes to improving the environmental situation, increasing competitiveness and reducing the country's energy dependence [13]. Of course, the production of biofuels from algae has its drawbacks, but it should be noted that they are much smaller than in the production of terrestrial plants.

As for the shortcomings of algae bioenergy, researchers at Sustainable Green Technologies have previously faced the problem of low oil yields. But the company has successfully developed the Lipi Trigger method, which has helped to synthesize almost 3 times more oils without disrupting plant growth, so this problem has become a problem [14]. We propose to move on to more mathematical and specific characteristics that are listed in the following three tables.

Economic block

Now you can observe the economic performance of various terrestrial plants and algae (Table 2). The following plants were used for comparison: sunflower, corn, rapeseed, soybeans and algae. And among the characteristics: the cost of equipment, the duration of the growing cycle, yield, and fat content. Looking at this table, we can say that algae are in the lead in all respects, in other words, one characteristic complements another and makes up the whole picture of attractive indicators.

By comparison, we can say that these parameters of algae can not even be close to the parameters of terrestrial plants.

For example, take corn, the growing cycle would not seem large, even the lowest among terrestrial 6–25 days, but the fat content is not attractive, moreover, their rate is the lowest of all. Well, here I think everything is clear and algae occupy the honorable first place of the economic block.

Table 2

Comparative analysis of economic characteristics of biofuels [15]

Plant	Cost of equipment	The duration of the growing cycle	Crop capacity (2017–2020)	Fat content per 0.4ha
Sunflower	The price of equipment for sunflowers is hsgher than ordinary firewood	6 – 8 weeks	10.1 – 14.2 million tons	408.8L
Corn	The cost of plant equipment - $200 million	6 – 25 days	35.8 – 40.2 million tons	68.4L
Rapeseed	450 thousands of dollars	45–55 days	1-1.2 million tons	480.7L
Soy	3 058 523.28 UAN	95–110 days	1.8 – 2 million tons	181.7L
Algae	4300 dollars	3–10 days	500 million tons	Natural conditions – 7003L Lab. conditions – 18 927 – 56 781L

Assesment of biofuel production from microalgae

The average annual productivity of microalgae growth in biomass, when cultivated in a photobioreactor in the weather conditions of Ukraine can be taken 11.5 kg/m^2 of the surface of the working area of the photobioreactor (culture medium) [16; 17]. The average lipid productivity will be 4.1 kg/m^2.

Provided that the wastewater is in the working area of the photobioreactor as a culture medium for an average of 3 days, the total volume of the working areas of photobioreactors for wastewater treatment of the urban population of Ukraine will be:

$$5.8\times10^9 \times 3 = 17.4\times10^9 \text{ l, or } 17.4\times10^6 \text{ m}^3.$$

If the thickness of the effluent layer as a culture medium in the working area of the photobioreactor does not exceed 0.2 m, the total area of all photobioreactors should be

$$\sum S_{photobioreactor} = \frac{17.7\times10^6}{0.2} = 87\times10^6 \text{ m}^2.$$

Thus, the annual increase in biomass of microalgae can be:

$$M_{biomass} = 87\times10^6 \times 11.5 = 1000.5\times10^6 \text{ kg}.$$

The annual increase in lipids will be:

$$M_{lipid} = 87\times10^6 \times 4.1 = 356.7\times10^6 \text{ kg}.$$

In real conditions, with the efficiency of removal of microalgae biomass from wastewater 90% (data for centrifugation), the efficiency of separation of lipids from biomass of microalgae 90 %, as well as energy efficiency of processing lipids into biofuels 90 % annual mass of biofuel (biodiesel)

$$M_{biofuel} = 356.7\times10^6 \times 0.9\times0.9\times0.9 =$$

$$= 260.0\times10^6 \text{ kg}.$$

Given that the density of biodiesel is 0.86 kg / l, the volume of biodiesel obtained will be:

$$W_{biofuel} = \frac{260.0\times10^6}{0.86} = 302.4\times10^6 \text{ l}.$$

Assuming the price of one liter of biodiesel at UAH 28, the total annual profit from the sale of biodiesel will be:

$$\Pi_{biofuel} = 302.4\times10^6 \times 28 =$$

$$= 8466.2\times10^6 \text{ UAH}.$$

Assessment of biogas production from organic waste

Calculation of the biogas yield:

$$V_{biogas} = m\times n,$$

where V_{biogas} — volume of the biogas income; m — mass of organic waste collecting during 1 year; n — amount of biogas generated from 1 tone of the organic waste.

The 350 m^3 of biogas generated from 1 tone of the organic waste.

$$V_{biogas} = 11\,731\,516\times350 = 4\,106\,030\,656 \text{ (m}^3\text{)}.$$

Calculation the volume of methane present in biogas:

$$V_{methane} = \eta\times V_{biogas},$$

where $V_{methane}$ — volume of methane present in biogas; η — percentage of the methane content in biogas; V_{biogas} — volume of the biogas income.

The approximate percentage of methane content in biogas equals 80 %.

$$V_{methane} = 0.8\times4\,106\,030\,656 = 3\,284\,824\,525 \text{ (m}^3\text{)}.$$

Calculation of the methane cost (income after 1 year of exploitation):

$$C = V_{methane}\times b,$$

where C — the methane cost (UAH); b — 1 m^3 methane cost.

The 1 cubic meter of methane cost 15.50 UAH.

$$C = 3\,284\,824\,525\times15.50 = 50\,914\,780\,134 \text{ (UAH)}.$$

Calculation the cost of fertilizer from biogas reactors:

$$C_a = \eta_1\times V_{org}\times f,$$

where C_a — cost of fertilizer from biogas reactors; η_1 — the percentage of the dry fertilizer from amount of organic waste; f — the fertilizer cost from 1 m^3.

The approximate percentage of the dry fertilizer from all amount of organic waste equals 25 %. This explained by drying of the organic fertilizers for further usage, from the one hand, and by the second usage of the residue as a substrate for new cycle in the reactor, on the other hand. The fertilizer cost from 1 m^3 equals 250 UAH.

$$C_a = 0.25\times83\,796\,544\times250 =$$

$$= 5\,237\,284\,000 \text{ (UAH) [18]}.$$

Ecological block

Next we will analyze the ecological and at the same time the most interesting block for us (Table 3). The plants we have remained the same, and among the parameters: production area, chemical reagents and emissions into the atmosphere. As for the production area, everything is obvious, but algae can occupy minimal areas, while giving a large amount of yield. In addition, algae do not require preparation and fertilization and are very easy to grow. As already mentioned, there are two types of conditions for growing algae: phototrophic conditions and heterotrophic conditions (lack of light, the presence of glucose as a carbon source and the presence of organic molecules as raw materials). And all of them are not only not expensive, but also environmentally friendly. According to the indicators of terrestrial plants, they all require the application of fertilizers, and accordingly create emissions into the atmosphere [19].

Table 3

Comparative analysis of ecological characteristics of biofuels [20-23]

Plant	Production area (2018 – 2020)	Chemical reagents	Emissions into the atmosphere
Sunflower	4000 – 7000 thousand hectares	Synthetic additives and chemical compounds are not used in the production. However, fertilizers are used during germination	No dangerous volatile substances or allergens are released during combustion. The volumes of carbon dioxide emitted are insignificant, so the atmosphere is not particularly damaged
Corn	4000 – 5000 thousand hectares	Requires significant application of mineral fertilizers and plant protection products	In general, the use of corn for energy purposes can reduce greenhouse gas emissions by 30%
Rapeseed	61.6 thousand hectares	Rapeseed yields require more fertilizer than grain	Emissions of volatile organic compounds, in particular hexane, in interaction with nitrogen oxides cause the formation of photochemical smog, which adversely affects almost all components of ecosystems
Soy	112.5 thousand hectares	When grown, it requires the application of fertilizers with micro- and microelements	Because soy require fertilization, it has a fairly significant percentage of greenhouse gas emissions and other harmful substances into the atmosphere
Algae	7500000 thousand hectares	Growing algae does not require preparation and fertilization	Growing algae can help solve the problem of the greenhouse effect

Social block

So we moved on to the last, social block, which includes such parameters as: competition in the market, production in Ukraine and the scale of traditional fuel replacement (Table 4). The table is simple and everything is clear here. The only thing I want to say is that Ukraine is really capable of growing algae, because it has everything it needs, it is algae with a high fat content, which are grown in the Black Sea, Dnieper, and equipment for their processing, which is also produced in Ukraine. The whole table is identical, the only thing is that these algae do not compete in the Ukrainian market, which is convenient [16; 23; 24].

Table 4

Comparative table of social characteristics of natural fuels [15]

Plant	Competition in the market (+/–)	Production in Ukraine (+/–)	Traditional fuel replacement score (1–5)
Sunflowers	+	+	5
Corn	+	+	5
Rapeseed	+	+	5
Soy	+	+	5
Algae	-	+	5

Conclusions

Organic susstance as microalgae have been experimented as a potential feedstock for biofuel generation in current era owing to its' rich energy content, inflated growth rate, inexpensive culture approaches, the notable capacity of CO_2 fixation, and O_2 addition to the environment. Thus, the development of bioenergy from algae is cost-effective and investment-attractive, helps to improve the environmental situation, increase competitiveness and reduce energy dependence of the country. Currently, research is ongoing towards the advancement of microalgal-biofuel technologies.

The implementation of the technology of biofuel production from organic waste also warns of danger, first of all for people. By reducing free waste, use it as a secondary material and benefit from it. Integrated waste management technology includes successive steps that take into account the environmental, economic and social spheres of life. After analyzing the economic efficiency of the biogas reactor system, we can recommend one or another system to generate revenue from garbage collection.

REFERENCES

[1] Bioenergy. URL: https://saee.gov.ua/uk/ae/bioenergy (access date 10.01.2022).

[2] Klimchuk Andrew (2016). Biofuels from seaweed. URL: https://alternative-energy.com.ua/uk/ biopalivo-z-morskih-vodorostej/ (access date 10.01.2022).

[3] Shevchuk G. V. (2021). Biofuels with algae as direction development. «Green» economics: current state and prospects. Vol.36. pp. 26–28 http://efm.vsau.org/storage/articles/October2021/wGo20jPv2gIwGDo29O5c.pdf (access date 10.01.2022).

[4] Biodiesel from algae (2018). Energy. URL: https://eenergy.com.ua/baza-znan/biodyzel-z-vodorostej/(access date 10.01.2022.)

[5] Emad A Shalaby (2011). Algae as promising organisms for environment and health. Plant Signal Behav. Vol. 6(9), pp. 1338–1350. https://doi.org/10.4161/psb.6.9.16779.

[6] Klimchuk Andrew (2016). Biofuels from seaweed. URL: https://alternative-energy.com.ua/uk/biopalivo-z-morskih-vodorostej/(access date 12.01.2022).

[7] Firoz Alam, Saleh Mobin, Harun Chowdhury (2015). Third Generation Biofuel from Algae. Procedia Engineering. Vol. 105., pp. 763–768. https://doi.org/10.1016/j.proeng.2015.05.068.

[8] Shamanskyi S., Boichenko S., Khrutba V., Barabash O., Shkilniuk I., Yakovlieva A., Topilnyckyi P., & Pavliukh L. (2021). Improving the photobioreactor operation efficiency in the technological scheme of wastewater treatment. Eastern-European Journal of Enterprise Technologies, 6, 10 (114), pp. 6–15. https://doi.org/10.15587/1729-4061.2021.248746.

[9] Khan M.I., Shin J.H. & Kim J.D (2018). The promising future of microalgae: current status, challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. Microb Cell Fact. Vol. 17 (36) https://doi.org/10.1186/s12934-018-0879.

[10] Shevchuk G.V. (2021). Biofuels with algae as direction development «Green» economics: current state and prospects. Vol .36., pp. 29 (access date 11.01.2022).

[11] Sophie Fon Sing, Andreas Isdepsky, Michael A. Borowitzka & Navid Reza Moheimani (2013). Production of biofuels from microalgae. Mitigation and Adaptation Strategies for Global Change. Vol. 18. pp. 47–72.

[12] Shamansky S.Y., Boychenko S.V., Pavlyukh L.I. (2017). Modeling of mass and lipid productivity of microalgae cultivation in Kyiv region. Energy: economics, technology, ecology. No 4. P. 184–192. DOI: https://doi.org/10.20535/1813-5420.4.2017.127566.

[13] Titlova O. O. (2015). Algae as an alternative energy source. URL: https://www.researchgate.net/publication/283553261_ VODOROSTI_AK_ ALTERNATIVNE_DZERELO_ENERGII (access date 15.01.2022).

[14] How much biofuels are produced in Ukraine and in the world (2018). URL: https://www.slovoidilo.ua/2018/07/03/infografika/suspilstvo/skilky-biopalyva-vyroblyayut-ukrayini-ta-sviti (access date 17.01.2022).

[15] Climatic conditions of the southern regions allow to successfully grow many valuable energy crops, in particular: miscanthus, sea and freshwater algae and amaranth (2018). URL: https:// super-agronom.com/news/5888-viznacheno-yaki-energetichni-kulturi-pridatni-do-viroschuvannya-na-pivdni-ukrayini (access date 17.01.2022)

[16] Shamanskyi S., Boichenko S., Pavliukh L. (2018). Estimating of microalgae cultivation productivity for biofuel production in Ukraine conditions. Proceedings of the National Aviation University. No 3. Vol.76, pp. 67–77. https://doi.org/ 10.18372/2306-1472.76.13161

[17] Shamansky S. (2018). Estimation of energy and economic efficiency of cultivation of microalgae for biofuel production in Ukraine. Ecological safety. Vol. (25). No. 1. P. 52–60.

[18] Pavliukh L.I., Syrotina I.O. Todorovych O.S. (2020). Strategy of exhaust municipal waste landfill recultivation. Proceedings of the National Aviation University. Vol. 82. No 1. P. 64–72. https://doi.org/10.18372/2306-1472.82.14613

[19] Skoruk O. P., Tokarchuk D.M., Vsemirnova V.M. (2011). Prospects of production of third generation of third biofuels Vol. 171-176. pp. 172-173. URL: http://socrates.vsau.org/repository/getfile.php/9529.pdf (access date 20.01.2022)

[20] Gonzalez L.E, Diaz G.C, Aranda D.A, Cruz Y.R, Fortes M.M. (2015). Biodiesel production based in microalgae: a biorefinery approach. Nat Sci. Vol. 7. pp. 358–369. https://doi.org/ 10.4236/ns.2015.77039.

[21] Ramya Ganesan, S.Manigandan, Melvin S.Samuel, Rajasree Shanmuganathan, Kathirvel Brindhadevi, Nguyen Thuy Lan Chi, Pham Anh Duc, Arivalagan Pugazhendhi (2020). A review on prospective production of biofuel from microalgae. Biotechnology Reports. Vol. 27. https://doi.org/10.1016/j.btre.2020.e00509.

[22] Skoruk O.P., Tokarchuk D.M., Vsemirnova V.M. (2011). Prospects of production of third generation third biofuels. Vol. 1 (48). pp. 171–176. URL:http://socrates.vsau.org/repository/getfile.php/9529.pdf (access date 20.01.2022).

[23] While the Dnieper is ”blooming” Kremenchug residents will not be left without gas (2017). URL: https://www.telegraf.in.ua/topnews/10063947-poki-dnpro-cvte-kremenchuzhani-ne-zalishatsya-bez-gazu.html (access date 20.01.2022)

[24] Pavliukh L., Shamanskyi S., Boichenko S. and Jaworski A. (2020). Evaluation of the potential of commercial use of microalgae in the world and in Ukraine. Aircraft Engineering and Aerospace Technology. Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/AEAT-08-2020-0181.

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ОЦІНКА ТЕХНОЛОГІЙ ВИРОБНИЦТВА БІОПАЛИВА З МІКРОВОДОРОСТЕЙ ТА ОРГАНІЧНИХ ВІДХОДІВ

Вступ. *На сьогодні, переробка органічних речовин, таких як органічні відходи або мікроводорості, є важливим способом отримання відновлюваних джерел енергії. Для підтримки процвітаючого життя населення надзвичайно важливо знайти відновлювані джерела енергії.*

Постановка проблеми. *В недалекому майбутньому мінеральні та органічні запаси земних надр перестануть задовольняти всезростаючі енергетичні потреби цивілізації. Вже сьогодні з'явилися технології, що дозволяють виробляти органічне паливо на основі багатьох видів рослин. Але вирощування таких культур призводить до виснаження земельних ресурсів. Іншими словами, верхній і тонкий родючий шар гумусу поступово виснажуються, що може вивести з використання мільйони або й мільярди гектарів орних угідь. Тому заміну звичайних наземних культур приходять мікроводорості.*

Методологія дослідження. *Дослідження ґрунтувалось на аналізі теоретичних досліджень та порівнянні різних типів біологічних палив з рослинназемного типу та з мікроводоростей, на економічному, екологічному та соціальному рівнях.*

Результати та обговорення. *Біодизель з мікроводоростей — паливо третього покоління, яке отримують шляхом переробки рослинної сировини. Як відомо, водорості характеризуються високим вмістом жирних кислот, які є основоюдля виробництва біодизелю.Мікроводорості дуже дешева і, одночасно, — високопродуктивна сировина. З одного гектарумікроводоростей отримують в 30 разів більше біопалива, ніж з гектару сої. При цьому біопаливо з водоростей на 5–10 % енергоємніше, ніж біодизель з рослинних олій. Крім того, мікроводорості досить швидко ростуть. Наприклад, водорості, що на 80% складаються з речовин, аналогічних за походженням нафті, виростають за 10 днів, тоді як ті ж самі водорості, що на 30 % складаються з речовин аналогічних за походженням нафті, виростають лише за три дні. Ще одним плюсом використання водоростей можна вважати той факт, що на відміну від вирощування інших видів рослинної сировини, їх немає необхідності підгодовувати і удобрювати – для зростання вони використовують вуглекислий газ (CO_2). При цьому чим вище концентрація вуглекислого газу, тим швидше вони культивуються. Таким чином, вирощування мікроводоростей може вирішити відразу декілька проблем: проблему парникового ефекту; проблему зайнятості посівних площ; проблему, пов'язану з дефіцитом традиційних видів палива і багато інших не менш важливих проблем.*

Висновок. *Органічна речовина у вигляді мікроводоростей експериментується як потенційна сировина для виробництва біопалива в поточну епоху завдяки її багатому енергетичному вмісту, підвищеній швидкості росту, недорогим підходам до вирощування, помітній здатності фіксації CO_2 та додаванню O_2 в навколишнє середовище. Впровадження технології виробництва біопалива з органічних відходів також попереджає про небезпеку, перш за все для людей. Зменшуючи вільні відходи, використання їх як вторинний матеріал і отримання від цього користь. Інтегрована технологія поводження з відходами включає послідовні кроки, які враховують екологічну, економічну та соціальну сфери життя.*

Ключові слова: мікроводорості; органічні відходи; біопаливо; екологічна безпека; сталий розвиток.

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ASSESSMENT OF BIOFUEL PRODUCTION TECHNOLOGIES FROM MICROALGAE AND ORGANIC WASTE

Introduction. *Today, the processing of organic matter, such as organic waste or microalgae, is an important way to renewable energy sources. To maintain a prosperous life of the population, it is critical that renewable sources of energy be found.*

Problem statement. *In the near future, mineral and organic reserves of the earth's interior will cease to meet the growing energy needs of civilization. Already today, technologies have emerged that allow the production of fossil fuels based on many plant species. But the cultivation of such crops leads to depletion of land resources. In other words, the top and thin fertile layer of humus is gradually depleted, which can lead to the use of millions or billions of hectares of arable land. And here to replace usual terrestrial cultures come microalgae.*

Research methodology. *The study was based on the analysis of theoretical studies and comparison of different types of biological fuels from plant-type and microalgae, at the economic, environmental and social levels.* ***Results and discussion.*** *Biodiesel from microalgae is a third generation fuel obtained by processing vegetable raw materials. It is known that algae are characterized by a high content of fatty acids, which are the basis for the production of biodiesel. Microalgae are very cheap and, at the same time — highly productive raw materials. One hectare of microalgae produces 30 times more biofuel than one hectare of soybeans. At the same time, biofuel from algae is 5-10% more energy-intensive than biodiesel from vegetable oils. In addition, microalgae grow quite rapidly. For example, algae, which is 80% composed of substances similar in origin to oil, grows in 10 days, while the same algae, which is 30% composed of substances similar in origin to oil, grows in only 3 days. Another advantage of using algae is the fact that, unlike growing other types of plant materials, they do not need to be fed and fertilized — they use carbon dioxide (CO_2) for growth. The higher the concentration of carbon dioxide, the faster they are cultivated. Thus, the cultivation of microalgae can solve several problems: the problem of the greenhouse effect; the problem of employment of sown areas; the problem of shortages of traditional fuels and many other equally important problems.*

Conclusion. *Organic susstance as microalgae have been experimented as a potential feedstock for biofuel generation in current era owing to its' rich energy content, inflated growth rate, inexpensive culture approaches, the notable capacity of CO2 fixation, and O2 addition to the environment. The implementation of the technology of biofuel production from organic waste also warns of danger, first of all for people. By reducing free waste, use it as a secondary material and benefit from it. Integrated waste management technology includes successive steps that take into account the environmental, economic and social spheres of life.*

Keywords: microalgae; organic waste: biofuel; environmental safety; sustainable development.

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