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PROSPECTS FOR PRODUCTION AND CONSUMPTION OF SECOND GENERATION BIOFUELS IN UKRAINE[1]

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ABSTRACT

The article analyzes the current state of production of second generation biofuels in the world and evaluates the possibility of launching such production in Ukraine. The work is topical due to the fact that liquid biofuels can replace a certain share of motor fuels consumed in Ukraine, thus contributing to the strengthening of the country's energy independence. The purpose of the study is to assess feasibility of a project on the production of second generation bioethanol in Ukraine; the task is to carry out a preliminary feasibility study for such a project. The analysis of the study of pure co-substrate fermentation and as a supplement for cattle manure proves that the maximum biogas yield obtained using alcohol stillage in a ratio of 40-80% increased compared to fermentation of pure cattle manure. The use of pure bards compared to the bard and the slurry mixture increases the maximum yield of biogas. It was found that the biogas obtained from the use of alcohol stillage is a high con-sumption of biogas with the methane content of between 70 and 78%.

Introduction

The study is topical due to the need of developing renewable energy in Ukraine in order to reduce the consumption of traditional fuels and energy, including the imported ones, and decrease greenhouse gas emission (Directive 2009/28/EC, 2018). Liquid biofuels are an important segment of the bioenergy sector as they can replace a certain part of motor fuels

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consumed in Ukraine (Romaniuk et al., 2018). The production and use of second generation liquid biofuels is of particular interest, in view of the possibility to meet the mandatory sustainability criteria set out in Directive 2009/28/EC on the promotion of the use of energy from renewable sources (Directive 2009/28/EC, 2018).

A review of literature

Some issues of the production of liquid biofuels in Ukraine with a focus on biofuels of the third generation (from algae) were analysed in the study (Skoruk, Tokarchuk, Vsemirnova, 2011). The authors of the paper (Skoruk, Grimaylo, 2011) considered the prospects for expanding biofuel production and increasing its competitiveness by the creation of clusters. Study (Geletukha, Zheliezna et al., 2016) analysed the compulsory sustainability criteria for liquid and gaseous motor biofuels defined by Directive 2009/28/EC.

There are 44 distilleries registered in Ukraine (Geletukha, Zheliezna et al., 2016), which totally produced 14.5 million dekaliters of ethanol in 2014 only (Nguyen, Bowyer, 2017). The output of alcoholic bard is 135-150 m^3 of ethanol per 1000 dekaliters (Geletukha, Zheliezna, et al., 2018), that resource is very significant. There are around 4 million m^3 of molasses and 3.6-3.8 mln m^3 grain bard, and about 8 mln m^3 of slightly contaminated wastewater I produced in Ukraine annually. This wastewater without treatment cannot be drained into water (Fuel and energy resources of Ukraine, 2017). In case of the majority of the plants molasses bard is not being utilized and is drained without purification with sewage into settling tanks where they rot (BP Statistical Review of World Energy, 2017), polluting groundwater and air (Global liquids …, 2018).

It is known that biogas yield of grain bards is 30-50 $m^3 \cdot ton^{-1}$ of substrate with the methane content of about 56% (What it costs to produce oil, 2018), for potato bard the measures are following: 26-42 $m^3 \cdot ton^{-1}$ of substrate with methane content of about 52% (Planning and installing bioenergy systems, 2005).

However, the use of raw bards in most cases (Demirbas, 2009) is only possible to the limited extent due to a low content of dry matter in it (about 6%) and the associated difficulties with transportation (Găgeanu, Voicu, et al., 2017). The bard is evaporated (Lu, Tabil, et al., 2013) or dried before used.

Technology Bards preparation before use is as follows:

1. Mechanically divided bard into the wet precipitate of insoluble materials (pellet) and filtrate with substances diluted in it. Using separators and centrifuges would be the best for these purposes. The result is 10 tons of pellet with humidity of 65% and 90 tons of hot filtrate containing dissolved solids, salts and acids of about 4% in it.
2. The pellet is dried in a simple and reliable way, preferably without the additional cost of steam, because not all boiler-house would tolerate additional load. There is appropriate equipment that allows removal of 6 t of moisture (6% of total weight). The process will be easier if the pellet is pre-mixed with dry grain shells that would absorb the part of the moisture due to its capillary-porous structure. It is easier to extract this moisture from the overall increased surface at low relative humidity.
3. The liquid filtrate is separated by membranes methods resulting 25% of the creamy brown concentrate (16 tons) and clean hot water (74 tons). Modern two-stage ceramic membranes facilities, makes it possible to reliably perform this separation even at high

temperatures filtrate up to 100°C inclusive. There are techniques able to increase the percentage of division by obtaining a multiple filter layer with an addition of special additives to initial bard. Salt content in the water is two times lower than in tap water, therefore, it is beneficial in bringing back to the process of alcohol production.

4. Protein Concentrate is also dried in a different type of a drying device with a higher strain in whole space of the dryer to moisture. Removing of the moisture by drying in the amount of about 12 tons (12% of the total initial weight) is quite difficult process, too.

Thus, two dry products with a different biological value and different costs are obtained as the output (Jezerska, Zajonca, et al., 2014).

However, as the bard is easily decomposed, in anaerobic conditions environment overacidation occurs quickly. Therefore, when using pure bards only two-stage technologies should be used not to overload the methane bacteria (Narra, Tao, et al., 2010). When using co-fermentation with other agricultural substrates for a single-stage technology, they should be carefully selected, but due to the high water content in bard it is good material to be used with the dry matter content (Stahl, Berghel, et al., 2012).

Purpose of work and scope of work

Purpose of work is to assess the viability of the project on the production of second generation bioethanol in Ukraine; the task is to carry out a preliminary feasibility study for such a project.

Research methodology

Materials and methods of the research include a review of plants existing in the world which produce second generation liquid biofuels, assessment and analysis of the main technical and economic indicators of a typical project of this type for Ukraine's conditions.

Research results

Today there is no common definition for liquid biofuels of the second generation. Usually it is considered that they are biofuels produced from lignocellulosic raw materials. Directive 2009/28/EC on the promotion of the use of energy from renewable sources states that lignocellulosic material means material composed of lignin, cellulose and hemicellulose such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes (Directive 2009/28/EC, 2018). Lignocellulosic raw materials also include by-products, waste and residues of agriculture (straw, corn stalks, sunflower stalks, etc.).

The main advantage of liquid biofuels of the second generation as compared to the first generation biofuels (that is "traditional" bioethanol and biodiesel produced from sugar-/ starch- and oil-containing raw materials, respectively) is that they are obtained from feedstock that does not compete with the production of food products. Directive 2009/28/EC gives a definition for non-food cellulosic raw materials, which, inter alia, include straw, husk, and grassy energy crops with a low starch content (miscanthus, switchgrass and some others).

The global large-scale commercial production of the second generation liquid biofuels has begun in 2014-2015. Most active investors in this sector are the USA, some EU countries, and Brazil. Currently, there are 67 plants in the world for the production of biofuels of this type, including 24 commercial, 19 demonstration and 24 pilot plants (table 1). Most installations, including the commercial ones, are located in the United States (table 2). In October 2015, a DuPont plant, the world's largest installation for the production of 2nd generation bioethanol from grain corn waste, began operation in Nevada (Iowa).The installed capacity of the plant is over 110 million litres of the final product per year. In general, according to data of 2015, 144 million tons of biomass (mainly grain corn waste) were used in the United States for production of liquid biofuels, which covered 5% of the country's annual demand for motor fuels (Que, Nguyen, Jim, Bowyer, 2017).

Table 1.
Number of Operating Second Generation Biorefineries in the World

Region	Type of plants			**Total**
	Pilot	Demonstration	Commercial	
Africa	5	0	3	**8**
Asia-Oceania	6	5	4	**15**
Europe	7	7	5	**19**
North America	5	6	9 (including 8 in USA)	**20**
South America	1	1	3	**5**
Total	**24**	**19**	**24**	**67**

Table 2.
List of Operating Cellulosic Ethanol Plants in USA and Brazil

Name, location	Feedstock	Scale	Year Operations Began	Capacity, million l·year^{-1}
USA:				
American Process, Alpena (Michigan)	Wood chips	Commercial	2012	3,6
American Process, Thomaston (Georgia)	Wood chips	Commercial	2013	no data
Calgren Renewable Fuels, Pixley (California)	Cow manure	Commercial	2015	no data
DuPont, Nevada (Iowa)	Corn	Commercial	2015	114
Gulf Coast Energy, Livingston (Alabama)	Wood waste	Pilot	2009	76
Indian River Bioenergy Center, Vero Beach (Florida)	Municipal solid waste	Commercial	2013	30

Name, location	Feedstock	Scale	Year Operations Began	Capacity, million l·year^{-1}
LanzaTech, Soperton (Georgia)	Wood waste	Pilot	2014	0,34
Pacific Ethanol, Stockton (California)	Corn kernel fiber	Commercial	2015	2,8
Project Liberty (POET), Emmetsburg (Iowa)	Corn stover, corn cobs, leaves, husk, stalk	Commercial	2014	76
Quad-Country, Galva (Iowa)	Corn kernel fiber, corn	Commercial	2014	7,6
Renmatix, Rome (New York)	Wood chips, tall grasses, corn stover, bagasse	Demonstration	2008	no data
Summit Natural Energy, Cornelius (Oregon)	Food processing and agricultural waste	Pilot	2009	no data
Tyton Biofuels, Raeford (North Carolina)	Tobacco waste	Pilot	2010	57
ZeaChem, Boardmen (Oregon)	Wood	Demonstration	2013	0,95
Brazil:				
Bioflex 1 (GrandBio), Alagoas	Bagasse, straw	Commercial	2014	No data
Dedini, Sao Paulo	Bagasse	Demonstration	2002	
Iogen, Sao Paulo	Bagasse	Commercial	2015	
Raizen, Sao Paulo	Bagasse	Commercial	2015	

There are three main technologies for cellulosic biofuels production: chemical, biochemical and thermochemical conversion (Fig. 1). Biochemical conversion of biomass into 2nd generation bioethanol includes three stages: pre-treatment of raw materials, hydrolysis and fermentation. The pre-treatment aims to destroy cell membrane of a plant. At the hydrolysis stage (in the presence of acid or enzymes), cellulose breaks down into less complex polysaccharides. Conversion of sugars into ethanol takes place in the process of fermentation. For the production of 2nd generation biodiesel, lignocellulosic raw material is subject to thermochemical conversion (pyrolysis, gasification).

The production of the second generation liquid biofuels is important as it offers an opportunity to meet the mandatory sustainability criteria defined by Directive 2009/28/EC. One of the criteria is greenhouse gas emission saving from the use of biofuels and bioliquids. This saving must be at least 50% from 01.01.2018 for biofuels and bioliquids produced in installations that were in operation on or before 05.10.2015. For installations that started operation after 05.10.2015, the greenhouse gas emission saving must be at least 60%. At present, in most cases only 2nd generation biofuels can meet the requirements. For example, Directive 2009/28/EC states that the typical greenhouse gas emission saving from the use of biofuels is (default value is in brackets): 87% (85%) for ethanol from wheat straw, 80% (74%) for ethanol from wood waste, 95% (95%) / 93% (93%) for diesel produced from wood waste / forest wood using Fischer-Tropsch technology. Similar indicators for the 1st generation biofuels are as follows: 61% (52%) for sugar beet ethanol, 32% (16%) for ethanol from wheat, 45% (38%) for biodiesel from rapeseed, and 58% (51%) for biodiesel from sunflower.

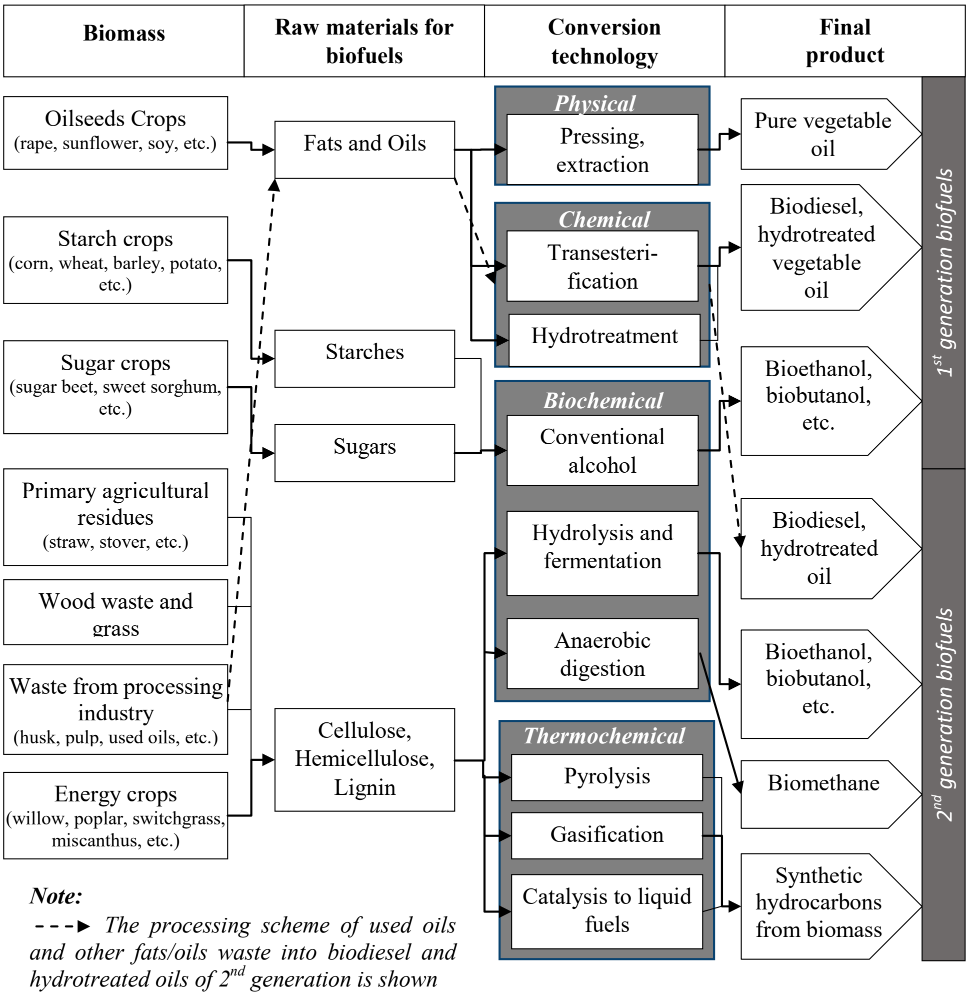

Figure 1. Production technologies for 1st and 2nd generation biofuels

In Ukraine, the production of "traditional" bioethanol and biodiesel did not become quite large-scale in due time. According to the data prepared by the State Agency for Energy Efficiency and Energy Saving of Ukraine for the Energy Community, only 3.8 kT of bioethanol were produced in Ukraine in 2017 (8.6 kT in 2016) while biodiesel was not produced at all in 2016-2017. At that, according to some conservative estimates, the potential of liquid biofuels production in Ukraine is about 1 Mt/yr for bioethanol and 180 $kT \cdot yr^{-1}$ for biodiesel (Geletukha, Zheliezna, et al., 2018).

The annual consumption of gasoline in Ukraine is about 2.2 Mt (including 145 kT in agriculture and forestry); the consumption of diesel fuel is 5 Mt (with 1.4 Mt in agriculture and forestry) (Fuel and energy resources of Ukraine, 2017). Partial replacement of traditional motor fuels with biofuels will reduce dependence of the country on fossil fuels and improve the environmental situation. In support of the development of this area, the draft Law "On amending some legislative acts of Ukraine regarding the development of liquid biofuels production and implementation of sustainability criteria for liquid biofuels and biogas intended for transport" was elaborated (No. 7348 of 9.11.2017).

It seems that for Ukraine it makes sense to actively develop the production and consumption of 2nd generation liquid biofuels. On the one hand, it requires much effort and investment, but on the other hand, it is the key to meeting the mandatory sustainability criteria for biofuels and it is investment in the future of the country.

The preparation and implementation of a specific project on the production of liquid biofuels requires thorough feasibility study. The payback period of project is strongly influenced by number of factors, including the cost of raw materials and the possible sale price of finished products. Results of the preliminary feasibility study of the production of ethanol from straw in Ukraine's conditions are presented in Table 3.

Table 3.
Prefeasibility study for 2^nd generation bioethanol production in Ukraine

Indicator	Value	
Productivity of final project	55 000 t/year	
Consumption of feedstock (straw)*	315 000 $t \cdot year^{-1}$ (wet mass)	
Feedstock price (straw)	18 $EUR \cdot t^{-1}$	
Capital costs*	109 million EUR	
Operating costs*	32 million $EUR \cdot year^{-1}$	
Loan (share of capital costs)	60%	
Loan rate	8%	
	Variant I**	Variant II***
Sale price of bioethanol	0.61 $EUR \cdot l^{-1}$	0.96 $EUR \cdot l^{-1}$
Income from the sale of bioethanol	42 million $EUR \cdot year^{-1}$	67 million $EUR \cdot year^{-1}$
Simple payback period	> 10 years	4.2 years
Discounted payback period (discount rate 7%)	> 10 years	5.1 years
Net present value (NPV)	---	179 mln. EUR
Internal Rate of Return (IRR)	---	25%

* Based on data of Biochemtex and Beta Renewables
** Sale of bioethanol in the Ukrainian market at a price corresponding to the average price of gasoline in Ukraine in August 2018
*** Sale of bioethanol in the EU at a price corresponding to the average price of gasoline in EU in August 2018

The results show that under the current conditions (including the ratio of gasoline price in Ukraine and Europe), the project is feasible only with the sale of the produced bioethanol in the European market (the payback period is within 5 years). For the possibility of profitable production and sale of bioethanol in the domestic market, it is necessary to find ways for reducing capital and operating costs of the project.

Conclusions

Production and use of second generation liquid biofuels is an important and promising segment of bioenergy in Ukraine. The development of this area will contribute to attaining renewable energy targets set by the National Renewable Energy Action Plan until 2020.

Ukraine has a big potential of biomass, including lignocellulosic raw materials, available for the production of second generation liquid biofuels. For the successful implementation of projects in this sector, it is necessary to improve the legislative framework and carry out scientific and practical work aimed to make the respective technologies cheaper.

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PERSPEKTYWY PRODUKCJI I ZUŻYCIA BIOPALIW DRUGIEJ GENERACJI NA UKRAINIE

Streszczenie. W artykule dokonano analizy aktualnego stanu produkcji płynnych biopaliw drugiej generacji na świecie w aspekcie rozpoczęcia produkcji na Ukrainie. Wykorzystanie biopaliw płynnych może przyczynić się do wzmocnienia niezależności energetycznej kraju. Celem badań jest ocena rentowności produkcji bioetanolu według ilości produkcji bioetanolu w kontekście cen benzyny na Ukrainie i sprzedaży jej na europejskich rynkach. Stwierdzono, że wykorzystanie odpadów z gorzelni jako dodatków do fermentacji zwiększyło wydajność uzysku biogazu do 40-80% w porównaniu z fermentacją odchodów bydlęcych bez dodatków, a zawartość metanu wynosiła 70-78%.

Słowa kluczowe: biomasa, biopaliwa, płynne paliwa, surowce lignocelulozowe, kryteria zrównoważonego rozwoju

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