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Food security and biofuel production: solving the dilemma on the example of Ukraine

Abstract: Today, ensuring energy security is becoming increasingly important. It has been proven that agricultural crops are currently the dominant feedstock for the production of biofuels and first-generation biofuels dominate both in Ukraine and around the world and can potentially pose a threat to food security. The research aims to analyze the state of food security in Ukraine in order to estimate the economic basis for the use of surplus food crops for biofuel production for substantiating the required areas for growing energy crops in the volumes that could ensure balance between the food and energy use of crops. An analysis of food security of Ukraine showed that the agricultural sector provides the population with most of the necessary food products, but it is advisable to modernize the food supply standards. It has been proven that crops that can be used for the production of first-generation biofuels in Ukraine are produced in sufficient quantities to ensure food security, and they are exported without compromising the food security of the state and export potential.

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As calculated, Ukraine can use about 11–12 million hectares of arable land for growing energy crops with their subsequent processing into biofuels. It has been proven that in the future in Ukraine, it is recommended to develop the production of biofuels (biogas and solid biofuels) from crop and livestock waste, as well as organic waste from processing enterprises. This would not pose a threat to food security and would address a number of environmental issues related to waste disposal. Today, under the condition of war in Ukraine, food security and energy independence are priority issues and energy diversity, including the production and consumption of biofuels, is a top factor for further development.

Keywords: waste, food security, energy security, feedstock, first- and second-generation biofuels

Introduction

Achieving a high level of development indicators of the state involves, above all, the rational use of the potential of its population. Providing the population with safe and affordable food is a direct duty of the state to its citizens, which is realized through food security. The issue of food security for Ukraine is currently extremely acute, which requires finding solutions to problems in this area (FAO 2022).

In addition to food, energy security is also important for any country. Only a well-balanced compound of food security and bioenergy activities gives the possibility to guarantee the country's self-sufficiency and economic and national autonomy (Yatsenko 2017). As a consequence of the shortage of fossil fuels, the use of agricultural and other crops as well as waste to produce energy is becoming increasingly essential. The positive aspects of biofuel production are the reduction of energy dependence, the creation of new jobs, the improvement of the environment, etc. (Dahman et al. 2019; Arshad et al. 2018). However, the use of food feedstock to produce first-generation biofuels may be a problem (Subramaniam et al. 2019; Ahmed 2020). For example, it can cause a situation in which a country with a decent amount of land will feel the lack of feedstock for the food industry as a consequence of the ambitions of agricultural producers to participate as provider of feedstock for biofuel companies (Pulyaeva et al. 2020).

Currently, more than 60% of bioethanol is made from corn, 25% from sugarcane, 2% from molasses, 3% from wheat, and the remaining part is produced from other grains, sugar beets or cassava (Table 1). According to OECD-FAO Agricultural Outlook 2021, more than 75% of produced biodiesel was obtained from vegetable oils (50%) and processed cooking oils (20%). New techniques that are involved in the production of so-called "second-generation biofuels" are centered on using cellulosic feedstock (agricultural crop byproducts, specialized energy crops or wood residues) are currently not being used for a substantial amount of total biofuel production. The world biofuel sector has been solidly impacted by national policies that target three purposes: support of agricultural producers, reduced greenhouse emissions and the strengthening of energy independence.

Table 1. Liquid biofuel production ranking and a major feedstock

Tabela 1. Ranking produkcji biopaliw ciekłych i wykorzystywane surowce

Country	Production ranking (base period)		Major feedstock	
	ethanol	biodiesel	ethanol	biodiesel
United States	1 (48.2%)	2 (18.1%)	corn	soybean oil, used cooking oils
European Union	5 (4.8%)	1 (32.3%)	sugar beet/wheat/corn	rapeseed oil/palm oil/ used cooking oils
Brazil	2 (26.7%)	4 (12.2%)	sugarcane/corn	soybean oil
China	3 (8.3%)	9 (2.3%)	corn/cassava	used cooking oils
India	5 (2.3%)	15 (0.5%)	molasses	used cooking oils
Canada	6 (1.6%)	13 (0.7%)	corn/wheat	canola oil/used cooking oil/ soybean oil
Indonesia	20 (0.1%)	3 (15%)	molasses	palm oil
Argentina	8 (1.0%)	5 (5%)	molasses/sugarcane/corn	soybean oil
Thailand	7 (1.4%)	7 (3.8%)	molasses/cassava/ /sugarcane	palm oil
Colombia	13 (0.44%)	11 (1.3%)	sugarcane	palm oil
Paraguay	14 (0.42%)	19 (0.03%)	corn/ sugarcane	jatropha

Source: OECD-FAO Agricultural Outlook 2021.

The Bioenergy Association of Ukraine, 2022, reports that according to the Energy Balance of Ukraine, the share of biofuels in the total primary energy supply (TPES) in 2018 amounted to 3.2 million toe, which is 3.4% of TPES.

According to OECD/FAO (2021), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), biofuel production to a major extent will remain dominated by "first generation" feedstock in spite of the increased vulnerability to the sustainability aspects of biofuel production remarked in various countries.

Nevertheless, the use of first-generation feedstock for biofuel production is opposed by NGOs and government institutions in many countries, motivated by possible competition between food and fuel and the negative effect on food security. Elshout et al. (2019) concluded that replacing fossil fuels with first-generation biofuels will probably have a negative impact on biodiversity, regardless of what type of feedstock is used or where this feedstock is produced. Besides Correa et al. (2017) emphasized that first generation biofuels will need large-scale agricultural areas in order to produce the amount necessary to replace traditional fuels, causing competition with food production. There is also a perception that food surplus countries should help developing countries overcome poverty and hunger, rather than using it for energy purposes. Finding the most cost-effective strategies for both food and energy security using agricultural feedstock is an important task for any country.

1. Literature review

Klochkovska et al. (2017) noted that currently, Ukraine's national economy incorporates into a global economy in which there is strong competition for limited financial resources and markets. Berezyuk et al. (2021) reported that the agrarian sector has a notable contribution to the growth of the national economy. The condition and tendencies of agrarian production development in Ukraine are highlighted by Sakhno et al. (2020). Varchenko et al. (2020) have studied sustainable food value chains and the role of state support in its support. According to the Law of Ukraine "On State Support of Agriculture of Ukraine," food security is the protection of human interests, which includes the state guarantee of unconstrained economic access to food in order to sustain everyday life. In the order of the Ministry of Economic Development and Trade of Ukraine dated 29.10.2013 "On approval of guidelines for calculating the level of economic security of Ukraine" the essence of food security is interpreted as the state of food production in the country that can fully meet the needs of quality, provided it is balanced and accessible to every member of society. Therefore, despite a certain difference in the interpretation of the essence of the concept of food security, the common factor in the definitions is the availability of food for humans.

Food security is characterized as a condition that exists when all people, at all times, have physical, social and economic access to adequate, safe and nutritious food that satisfies their dietary needs and food preferences for active and healthy life (FAO 1996).

Mowlds (2020) noted that by 2020, the conceptualization of food security was enlarged to include two other components: agency and sustainability. Sustainable development refers to the durable capability of systems to satisfy food security and nutrition needs in a way that does not compromise the economic, social or environmental foundations, and which will endure food security and nutrition for future generations.

According to Berry et al. (2015) efforts to incorporate sustainability within the framework of food security and vice-versa should be considered as work in evolution.

Msangi et al. (2010) explored the influence that fast increase in biofuel demand may have a negative influence on agricultural prices and on food security and nutrition. Their results clearly show a "food-versus-fuel" tradeoff that any national plan for biofuel expansion should consider. Kurowska et al. (2020) indicate that until now, a belief has existed that such biofuels compete with food production, harming food prices, thereby contributing to the growing problem of famine in the world.

However, the report of the Intergovernmental Panel on Climate Change (IPCC 2019) has shown that biofuels can lead to a significant reduction in environmental degradation and is forecasted to contribute to the net cutting of carbon emissions by 94% respective to fossil fuels, which is nearly at 60 percent. As stated by Subramaniam et al. (2020), the production of biofuels currently plays a key role in diverting the amount of agricultural supply for food production to biofuel production, causing the shortage of food supply.

As concluded by Escobar et al. (2009), the increase in the use of biofuels is inevitable and international cooperation, regulations and certification mechanisms should be settled concerning

the use of land and the lightening of environmental and social impacts effected by biofuel production.

This study is a continuation of the scientific achievements of the authors in the context of the study of the peculiarities of the use of food feedstock for energy purposes. Kaletnik et al. (2021) have identified the impact of public policies on biofuels on energy, environment and food security, as well as diversification of the feedstock base for biofuel production. Pryshliak et al. (2020) have studied the potential of agricultural waste for biofuel production as an alternative to food crops, Kaletnik et al. (2022) have investigated the potential of energy crops to their processing on solid biofuels in Ukraine.

To solve the food problem, scientists are studying the potential of non-food feedstock for the production of second- and third-generation biofuels. The potential of using lignin-cellulose feedstock and microalgae to produce biofuels continues to be investigated. Pankratz et al. (2019) note that in terms of the potential to lower costs using microalgae, the most significant mutual factor is the increment of average productivity (yield). Varela Villarreal et al. (2020) concluded that the existing technological readiness of microalgae use is low and cannot economically challenge oil fuels.

The issue of ensuring a balance between food security and the energy use of crops is quite multifaceted, which requires further research to substantiate the main directions of its solution.

2. Materials and methods

Theoretical methods, including abstraction, analysis-synthesis and induction-deduction are used to identify the approaches for understanding food security.

The practical study is based on secondary data from both the government and international sources. The parameters of collection of the data are the information value of documents, their availability and their coverage width. To ensure the data on different types of biofuels comparability coefficients from British Petroleum Statistical Review of World Energy were used. The data is analyzed using descriptive statistics and graphic methods.

A methodological approach to evaluation the possibility of biofuel production in Ukraine without endangering food security is developed by the authors. In order to study this problem, we calculated the required areas for sowing crops is needed to meet food security, analyzed the volume of food exports and calculated the potential for biofuel production in Ukraine from sown areas that currently meet the export needs of the state.

3. Results and discussions

The economic development of the territory and the formation of a stable level of financial-economic potential for rural communities is of particular importance both in Ukraine and in the EU countries (Vdovenko et al. 2021). The country's food security is an essential part of the economic growth of the state and guarantees its security in the context of economic and national factors and an element of international food security in general, which is influenced by many factors (Pronko et al. 2021).

There are different approaches for measuring food security:

1. The daily and annual amount of food is enough to guarantee the ordinary functioning of the human body and maintain health. It is provided with variety, balance and calorific content of the diet. According to the norms of physiological demands of the population of Ukraine in basic nutrients and energy recommended by the Ministry of Health of Ukraine, the daily energy needs of adults depend on gender, age and the activity group and range from 2,300 to 4,100 kcal per day for men and 1,800 to 3,050 kcal per day for women. In 2019, according to the State Statistics Committee of Ukraine, the daily energy value of the human diet amounted to 2,707 kcal. To calculate the area needed to meet food security in Ukraine, we will increase the available daily energy value of the human diet by 10%, according to the State Statistics Committee.

2. Determining the volume of necessary food products for the population of Ukraine (42.12 million people) (State Statistics Service of Ukraine 2020).

Analysis of the average annual consumption of basic foodstuffs in Ukraine from 2000 to 2020 shows that Ukrainians, by main groups, generally began to eat better. In particular, the average annual consumption per capita in 2020 increased compared to 2000 for the following food groups: meat and meat products – by 22.8 kg (due to a significant increase in the consumption of poultry meat by 84%); milk and dairy products – by 2.4 kg; fish and seafood – by 1.2 kg; eggs – by 5 pieces; fruits, berries and grapes – by 20.4 kg. However, we observe a decrease in the consumption of vegetables and melons by 15.6 kg, bakery products by 13.2 kg, and sugar by 3.6 kg per capita. The average annual consumption of basic foodstuffs by one person in Ukraine during 2000–2020 is provided in Table 2.

Most Ukrainians consume foods such as eggs, meat, vegetables and fruits, which indicates a change in the diet's structure. Despite the increase in food consumption, the structure of the diet remains unbalanced, as evidenced by a comparison of nutrition according to the consumer basket of the average Ukrainian with guidelines developed by the Ukrainian Research Institute of Hygiene and Nutrition of the Ministry of Health (Table 3).

The actual food consumption and the current food consumer basket do not meet the recommended norms of the Ministry of Health of Ukraine.

Ukrainians consume vegetables, melons and potatoes above the norm, while other types of products are consumed less than the recommended norms. Experts say that the volume of the consumer basket should be increased by 20–25% because the norms are significantly understated

Table 2. Dynamics of food consumption in households of Ukraine on average per year per capita [kg]

Tabela 2. Dynamika spożycia żywności w gospodarstwach domowych Ukrainy średniorocznie na 1 mieszkańca [kg]

Foodstuffs	2000	2005	2010	2015	2020	2020 to 2000, ±
Bread product	109.2	123.6	111.6	102.0	96.0	–13.2
Meat and meat products	39.6	52.8	61.2	55.2	62.4	22.8
including: - poultry meat	15.0	13.9	23.2	24.2	25.6	11.7
- pork	13.4	11.7	18.0	18.1	19.5	7.8
- beef	10.3	12.6	9.8	8.2	7.9	–4.7
Milk and milk products	224.4	260.4	230.4	237.6	226.8	2.4
Fish and fish products	15.6	21.6	21.6	14.4	16.8	1.2
Potatoes	122.4	115.2	92.4	79.2	72.0	–50.4
Eggs, pcs.	228	252	240	228	233	5
Oil	18.0	22.8	21.6	19.2	16.8	–1.2
Vegetables, water-melons, melons and gourds	120.0	109.2	114.0	105.6	104.4	–15.6
Fruits, berries and grapes	24.0	37.2	44.4	37.2	44.4	20.4
Sugar	32.4	43.2	36.0	33.6	28.8	–3.6

Source: formed by the authors based on the State Statistics Service of Ukraine.

and do not meet real human needs. For example, the consumer basket per calendar year includes 53 kg of meat and the real demand is 83 kg; milk consumption is 143 kg with the physiological norm being 380 kg.

Existing food standards and the real condition of the food basket in Ukraine are a violation of Article 48 of the Constitution, which declares that "everyone has the right to an adequate standard of living for himself and his family, including adequate food, clothing and housing". The combination of the above factors poses a threat to the food security of Ukraine and, accordingly, lowers the country's rating in the global community. And currently, considering the situation with the Russian invasion, the provision of Ukraine's population with food is so much worse.

Another measure of the country's food security which indicates the reliable availability of food is the Global Food Security Index – an assessment of food security in the world using an index that includes four components: the economic and physical availability of food; quality and safety; natural resources; sustainability (Global Food Security Index), which is calculated from 2012.

As of 2020, Ukraine ranks fifty-fourth among the countries in the world in the ranking of food security, which is generally a low figure (Fig. 1).

The leaders in the world ranking of food security are Finland and Ireland, which rank first and second, respectively (Global Food Security Index). According to experts of the international agricultural company, Corteva Agriscience, in the presence of technological solutions, attracting investment in the agro-industrial complex and integration into international supply chains, Ukraine can feed 500 million people (Ukraine ranked fifty-fourth in the Global Food Security Index 2020).

Table 3. Comparison of the food consumer basket in 2020 with the norms of consumption in Ukraine [kg]

Tabela 3. Porównanie koszyka konsumentów żywności w 2020 roku z normami spożycia w Ukrainie [kg]

Foodstuffs	Consumption rates recommended by the Ukrainian Research Institute of Hygiene and Nutrition of the Ministry of Health [kg/year]		Consumption rates by Resolution No 780 of the Cabinet of Ministers of Ukraine dated October 11, 2016 [kg/year]	Actual consumption in 2020 [kg/year]	Deviation of actual consumption in 2020 from the rational norm [%]
	minimal	rational			
Bread product	94.0	101.0	101.0	96.0	–4.95
Meat and meat products	52.0	80.0	53.0	62.4	–22.0
Milk and milk products	341.0	380.0	143.5	226.8	-40.3
Fish and fish products	12.0	20.0	13.0	16.8	–16.0
Potatoes	96.0	124.0	95.0	72.0	–41.9
Eggs, pcs.	231.0	290.0	220.0	233.0	–19.7
Oil	8.0	13.0	7.1	16.8	29.2
Vegetables, watermelons, melons and gourds	105.0	161.0	110.0	104.4	–35.2
Fruits, berries and grapes	68.0	90.0	64.0	44.4	–50.7
Sugar	32.0	38.0	24.0	28.8	–24.2

Source: formed by the authors based on State Statistics Service of Ukraine and Resolution of the Cabinet of Ministers of Ukraine of October 11, 2016, No780 "On approval of sets of food products, sets of non-food products and sets of services for the main social and demographic groups of the population".

The main strengths that determine Ukraine's Food Security Index are food security; a low share of the population below the poverty line; minimum food costs; low food losses. Factors such as a high level of corruption have the greatest negative impact in the form of expensive loans and political instability (Global Food Security Index). The main components of the food security index of Ukraine in 2020 are shown in Figure 2.

Thus, the level of food security in Ukraine is quite high, which cannot be said about energy security, which is threatening in Ukraine, as the state is unable to meet domestic oil and gas needs with its fossil fuels.

The theoretical threat to the country's food security is the allocation of part of agricultural land for growing feedstock for the production of biofuels, ensuring a high level of agricultural exports in order to increase gold and foreign exchange reserves.

To determine the required area of agricultural land that guarantee food security, the fund of food consumption, population and norms of consumption in kilocalories are taken into account. According to the Official Website of the State Service of Ukraine for Geodesy, Cartography and Cadastre, the total area of agricultural land suitable for production in Ukraine is 42.4 million hectares. As can be seen from Table 4, 11.555 million hectares are needed to meet the consumer needs of all residents of Ukraine (given that the volume of food imports will be provided within the country).

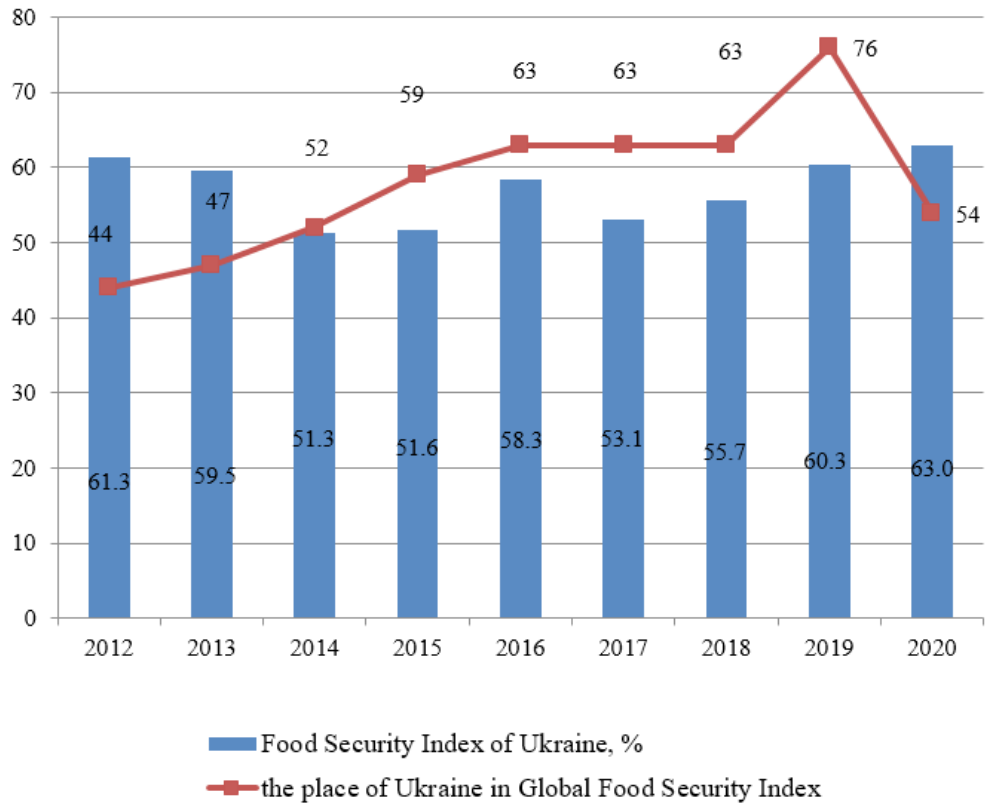

Fig. 1. The place of Ukraine in world ranging and its Food Security Index, 2012–2020
Source: composed according to Global Food Security Index

Rys. 1. Miejsce Ukrainy w światowym rankingu i jej indeks bezpieczeństwa żywnościowego, 2012–2020

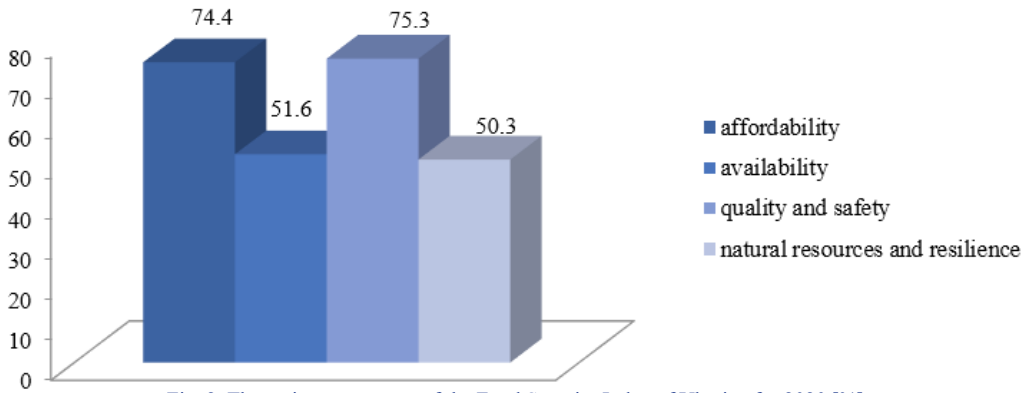

Fig. 2. The main components of the Food Security Index of Ukraine for 2020 [%]
Source: composed according to the data from the Global Food Security Index

Rys. 2. Główne składowe indeksu bezpieczeństwa żywnościowego Ukrainy za rok 2020 [%]

Table 4. Consumption of foodstuffs in Ukraine and calculation of areas for their production

Tabela 4. Spożycie środków spożywczych w Ukrainie i obliczanie powierzchni do ich produkcji

Products	Fund of consumption of main foodstuffs, 2020 p. (data from State Statistic Service of Ukraine) [thousands of tons]	Required area for cultivation [thousands hectares]	% of the required area for cultivation
Bread and bread products	4,034.2	1,613.7	14.0
Meat and meat products	2,244.1	4,936.6	42.7
Milk and milk products	8,430.3	2,361.1	20.4
Fish and fish products	517.4	103.5	0.9
Eggs and egg products	652.0	334.4	2.9
Vegetables, watermelons, melons and gourds	6,845.5	435.6	3.8
Fruits, berries and grapes	2,356.9	235.7	2.0
Potatoes	5,593.1	404.9	3.5
Sugar	1,161.3	387.1	3.3
Oil	512.4	743.0	6.4
Population 42,12 million people, consumption of 3000 kcal/day		11,555.5	100

Source: calculated by the authors according to the data from the Official Website of the State Statistics Service of Ukraine.

Thus, according to research, Ukraine needs a little more than 1/3 of the available agricultural land to respond to the domestic food needs of the population. Given the above calculations, the remaining arable land in Ukraine (20.946 million hectares) is used to meet export needs. Thus, exports of agricultural products in 2020 in monetary terms amounted to 22.2 billion US dollars. Simultaneously, imports of agricultural products to Ukraine last year amounted to 6.5 billion US dollars.

As a result of the above, Ukraine cannot completely abandon the export of agri-food products, because its share, together with food industry products, amounted to 45.1% in 2020 in the structure of total exports. It should be noted that the export of raw materials accounts for about 50% of all exports of agricultural products. An option for Ukraine is to use part of the exported crops for the production of bioethanol and biodiesel. These crops include starch, sugar and oilseeds, the export volumes of which are quite significant (Table 5).

As for the export of food products, in most cases, we are talking about products of primary processing (butter, meal, meat and offal). Thus, by increasing the volume of exports of finished products, Ukraine can receive the same foreign exchange earnings, while using much smaller amounts of arable land.

Thus, without threatening the state's food security and its export potential, Ukraine can use about 11–12 million hectares of arable land to grow energy crops with their further processing into biofuels for domestic consumption and the export of environmental energy resources. Con-

Table 5. Exports of certain food crops that can be used for biofuel production [thousand tons]

Tabela 5. Eksport wybranych roślin spożywczych, które można wykorzystać do produkcji biopaliw w Ukrainie [tys. ton]

Crops	2017	2018	2019	2020	2021	2021 to 2019 [+/–]
Potential feedstock for bioethanol production						
Corn	19,394.0	21,441.0	28,929.0	23,864.0	33,500.0	14,106.0
Wheat	17,314.0	16,373.0	20,022.0	16,851.0	24,200.0	6,886.0
Potential feedstock for biodiesel production						
Rapeseed	2,100.0	2,140.0	2,740.0	2,400.0	2,570.0	470.0
Soy	2,300.0	2,500.0	2,550.0	1,500.0	1,460.0	–840.0
Sunflower oil	5,341.0	6,063.0	6,686.0	5,273.0	6,650.0	1,309.0

Source: based on the Official Website of the State Statistics Service of Ukraine.

sider the potential opportunities of Ukraine for the cultivation of energy biofuels and biofuel production (Table 6).

The most promising way to resolve the food conflict in bioproduction on a global scale is the transition to second-generation biofuels, which makes it possible to abandon food crops as a bioenergy feedstock in favor of agricultural waste, waste from the woodworking industry, as well as fast-growing energy crops (e.g. energy willow, poplar). The main drawback of this type of fuel is the high cost of existing production technologies as well as the fact that only large-scale production with significant productivity; thus, large investments become economically viable. For example, the production of second-generation bioethanol with a capacity of 50 million gallons per year requires an investment of $375 million, while the production of bioethanol under the traditional scheme is $67 million. In general, the cost of producing second-generation biofuels is 30–70% higher than the first (Berezin 2002).

The use of bio-waste for biofuel production is also safe for food security. In particular, organic waste from the agricultural sector, sewage sludge and the organic fraction of household waste are potential feedstock for biogas production. Some types of crop waste (straw and husks of cereals, rice, corn, sunflower, etc.) can be used for the production of solid biofuels – briquettes and pellets.

The potential yield of biogas from livestock waste in Ukraine, considering that the biogas output from 1 ton of livestock waste (Kaletnik 2018) is 3009.0 million m^3 (according to the data on January 1, 2022) including the potential yield of biogas from cattle waste is 685.8 million m^3, from pig manure – 558.2 million m^3, sheep and goats' manure – 66.2 million m^3, horse manure – 95.8 million m^3, from poultry manure – 1603.0 million m^3 (Table 7).

Organic waste generated by processing enterprises also has energy potential and can be used for biogas production. This includes wastes from alcohol, beer, sugar and bioethanol plants. In particular, it is possible to produce biogas from post-alcohol bard produced at alcohol and bioethanol factories, beer bard (by-products of brewing), as well as from molasses (waste from

Table 6. Calculation of biofuel production potential in Ukraine

Tabela 6. Oszacowanie potencjału produkcyjnego biopaliw w Ukrainie

Crop	Planting area	Yield [tons per hectare]	Fuel yield. from 1 ton of feedstock	Fuel yield. from 1 ton of feedstock	The yield of fuel. tons of oil equivalent from 1 t of feedstock*	Fuel yield from 1 hectare [tons of oil equivalent*]	Fuel output total, million tons of oil equivalent
Bioethanol							
Sugar beets	1.5 million hectares	60.0	100 litters	0.079 tons	0.05	3.06	4.59
Corn	1.5 million hectares	7.0	416 litters	0.329 tons	0.21	1.48	2.22
Wheat	1.0 million hectares	5.0	395 litters	0.312 tons	0.20	1.00	1.00
Biodiesel							
Rapeseed	1.0 million hectares	1.8	420	0.36 tons	0.31	0.56	0.56
Soybean	1.0 million hectares	2.2	200	0.17 tons	0.15	0.33	0.33
Sunflower	1.0 million hectares	2.5	400	0.34 tons	0.29	0.73	0.73
Biogas							
Corn silage	2.0 million hectares	40.0	180 m^3	–	0.15	6.00	12.00
Sugar beet pulp	Sugar beet growing area (1.5 million hectares)	19.0	120 m^3	–	0.08	1.52	2.28
Solid biofuel							
Energy poplar, energy willow	0.5 million hectares	14.0 dry matter			0.43	6.02	3.01
Miscanthus, switchgrass	0.5 million hectares	10.0 dry matter			0.40	4.00	2.00
Total bioenergy production potential from 10 million hectares. million tons of oil equivalent							28.72

* The following coefficients were used in the calculations (British Petroleum. Statistical Review of World Energy. Approximate conversion factors 2021):

1 litter of bioethanol – 0,79 kg,
1 liter of biodiesel – 0.86 kg,
1 ton of bioethanol – 0.64 tons of oil equivalent,
1 ton of biodiesel – 0.86 tons of oil equivalent,
1 thousand m^3 of biogas – 0.812 tons of oil equivalent.
Source: calculated by the authors.

sugar factories). The potential output of biogas from this waste (according to data on January 1 2022) in Ukraine maybe 265.4 million cubic meters (Table 8).

Table 7. The potential output of biogas from livestock waste in Ukraine (on January 1, 2022)

Tabela 7. Potencjalna produkcja biogazu z odpadów zwierzęcych w Ukrainie (1.01.2022 r.)

Category	Presence of animals [thousand heads]	Accumulation of waste [t/year per 1 head]	Accumulation of total waste [million t/year]	Biogas output from 1 ton of substrate [m^3]	Biogas production potential [million m^3/year]
Cattle	2,689.4	10.2	27.4	25.0	685.8
Pigs	5,538.1	3.6	19.9	28.0	558.2
Sheep and goats	1,093.5	1.1	1.2	55.0	66.2
Horses	208.3	7.3	1.5	63.0	95.8
Poultry	208,184.0	0.055	11.5	140.0	1,603.0
Total			61.5		3,009.0

Source: calculated by the authors.

A big variety of feedstock that can be used to produce biogas allows the construction of biogas plants virtually everywhere where there is a high concentration of agricultural enterprises and other enterprises in industries that are technologically related to agriculture. The versatility of methods of further use of biogas as an energy resource allows it to be used for the production of electricity or heat at the place of its generation. Simultaneously, the permanence of electricity production from biogas during the year enables covering the network overload.

The conducting of this scientific study by the authors coincided with the beginning of the war of the Russian Federation against Ukraine, which began on February 24, 2022. Under these conditions, food and energy security is viewed very differently and involves:

- well-thought-out state policy on the distribution of available food resources between individual regions;
- diversification of the fuel and energy complex with an emphasis on renewable energy;
- a strong volunteer movement to collect food in regions where hostilities are less active and transport them to the most affected areas;
- a reduction of energy consumption by increasing energy efficiency and the introduction of efficient energy management.

The war on the territory of Ukraine is a potential threat not only to Ukraine's food security but also to many countries that import Ukrainian agricultural products. In particular, the largest importers of Ukrainian wheat are Egypt (27% of crop imports are from Ukraine), Indonesia (28%) and Pakistan (67%). The largest importers of Ukrainian sunflower oil are India (65% of imports are from Ukraine), EU countries (82%), and China (40%) (State Customs Service of Ukraine, 2021). Currently, the food security of Ukraine is questionable due to the impossibility of sowing in the territories under hostilities. Besides, there are problems with the provision of fuel, seeds and equipment. Due to these circumstances, the Ministry of Agrarian Policy and Food of Ukraine have limited the export of certain food crops (oats, millet, buckwheat). If the current military situation remains unsolved, problems with food supply will affect not only Ukraine but many other countries in Africa, the Middle East and Asia.

Table 8. The potential output of biogas from organic waste from processing plants in Ukraine (on January 1, 2022)

Tabela 8. Potencjalna produkcja biogazu z odpadów organicznych z zakładów przetwórczych w Ukrainie (1.01.2022 r.)

Type of processing plant	The main type of waste (by-products)	Total [million t/year]	Biogas output from 1 ton of substrate [cubic meters]	Biogas production potential [million cubic meters/year]
Breweries	Beer bard	2.4	49.0	116.4
Sugar factories	Molasses	0.5	166.0	83.0
Alcohol factories	Post-alcoholic bard	1.2	55.0	66.0
Total				265.4

Source: calculated by the authors.

Ukraine is an integral part of the European democratic space, where the greatest value is the citizen with his rights and freedoms. Today, our society and its values are being transformed by the harsh challenges of today, and we all look forward to the victory of democratic values in Ukraine, the revival of the destroyed infrastructure and the resumption of the agricultural and energy sectors to provide our food. In the long run, our state must gain full energy independence from the Russian Federation, and one of the potential ways to achieve this goal is the growth of biofuel production and consumption.

Conclusions

After analyzing individual indicators of food security, we can conclude that in Ukraine, its level is quite high, with the exception of certain types of products (fruits, berries, grapes). However, the food consumer basket in Ukraine today does not meet rational consumption standards. The analysis of existing norms confirmed the need for their modernization due to them being outdated and do not include some food products recommended by international organizations.

To improve the current state of Ukraine's food security and optimize the norms of food consumption by the average citizen and bring them closer to the scientifically sound recommendations given by the Ministry of Health of Ukraine, a set of measures should be taken at the state level. First of all, it involves the indexation of citizens' incomes taking into account inflationary processes.

Ensuring the country's food security is considered to be one of the main strategic tasks of the state and an integral part of national security; however, energy security is also important. Today, countries are increasing the production of first-generation biofuels, which could pose a possible danger to food security. Yet, such crops in Ukraine are produced in sufficient quantities; moreo-

ver, significant volumes are exported. Due to energy dependence, some of the exported products can be used for the production of first-generation biofuels with greater economic benefits at the macro level.

Currently, the energy sector of Ukraine is strongly affected by the war that Russian Federation started on the 24th of February against Ukraine. Ukraine has a huge shortage of oil products caused by the bombing of fuel bases, destroying the biggest oil-processing Ukrainian refinery in the Odessa region (Kremenchuk oil refinery). Sea ports are also being blocked by Russian marine forces. With this in mind, renewable energy and biofuels is the "light in the dark tunnel" for Ukraine. Currently, there is a strong deficit for fuel in every city in Ukraine and prices have risen almost by 50% (in just two months). Furthermore, the increase of fuel prices have also influenced the the increase in the prices of food products.

Calculations have shown that in order to not harm the country's food security, the allowable share of agricultural land allocated for the production of biofuels from food feedstock in Ukraine should not exceed 11–12%.

The production of biofuels from food feedstock is a temporary measure, as this could exacerbate the global food problem. The production of biofuels from non-food feedstock, especially from waste, is the most promising way to solve the food and energy dilemma.

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Bezpieczeństwo żywnościowe a produkcja biopaliw: rozwiązanie dylematu na przykładzie Ukrainy

Streszczenie

Dziś coraz większego znaczenia nabiera zapewnienie bezpieczeństwa energetycznego. Udowodniono, że uprawy rolne są obecnie dominującym surowcem do produkcji biopaliw, a biopaliwa pierwszej generacji dominują zarówno w Ukrainie, jak i na świecie i mogą potencjalnie stanowić zagrożenie dla bezpieczeństwa żywnościowego.

Celem przeprowadzonych badań jest analiza stanu bezpieczeństwa żywnościowego w Ukrainie w celu oszacowania ekonomicznej podstawy wykorzystania nadwyżek roślin spożywczych do produkcji biopaliw, aby określić, ile terenów jest potrzebnych do uprawy roślin energetycznych w ilościach zapewniających równowagę pomiędzy żywnością a energią wykorzystania upraw.

Analiza bezpieczeństwa żywnościowego Ukrainy wykazała, że sektor rolny dostarcza ludności większość potrzebnych produktów żywnościowych, ale wskazana jest modernizacja standardów zaopatrzenia w żywność. Udowodniono, że rośliny uprawne, które mogą być wykorzystane do produkcji biopaliw pierwszej generacji w Ukrainie są produkowane w ilościach wystarczających do zapewnienia bezpieczeństwa żywnościowego i są eksportowane bez narażania bezpieczeństwa żywnościowego państwa i potencjału eksportowego. Zgodnie z obliczeniami, Ukraina może wykorzystać około 11–12 mln hektarów gruntów ornych pod uprawę roślin energetycznych, a następnie przetwarzać je na biopaliwa. Stwierdzono, że w przyszłości Ukraina może rozwinąć produkcję biopaliw (biogazu i biopaliw stałych) z odpadów roślinnych i zwierzęcych oraz odpadów organicznych z zakładów przetwórczych. Takie działania nie stanowiłyby zagrożenia dla bezpieczeństwa żywnościowego i rozwiązałoby szereg kwestii środowiskowych związanych z usuwaniem odpadów. Dziś, w warunkach wojny na Ukrainie, bezpieczeństwo żywnościowe i niezależność energetyczna to kwestie priorytetowe, a różnorodność energetyczna, w tym produkcja i konsumpcja biopaliw, jest głównym czynnikiem dalszego rozwoju.

Słowa kluczowe: odpady, bezpieczeństwo żywnościowe, bezpieczeństwo energetyczne, surowce, biopaliwa I i II generacji