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ECONOMICS AND RISK MANAGEMENT OF BIOFUEL PRODUCTION IN AGRICULTURE

Abstract. The development of the biofuel market in the world has a positive dynamic for growth. The substantiation of the directions of further improvement of the methodology of production management of alternative fuels is taking into account the policy of climate change and the possibility of reducing dependence on external suppliers of traditional fuels. Ukraine has favorable natural and climatic conditions for the development of production of non-traditional fuels. The most common crops that can be grown in Ukraine for biofuels are rapeseed and corn. Based on the material and technical base and production conditions, rapeseed is the best crop for cultivation. Therefore, the object that we have chosen for this study is the production of biodiesel, which does not require significant capital expenditures by agricultural enterprises. For the purposes of the study, the risks were grouped according to various classification criteria (operational and production; marketing; financial; legal and infrastructural; weather; environmental) and the weights of their impact on the performance of agricultural enterprises. The structural scheme of the algorithm of the automated estimation of influence of risk factors for development of bases of the analysis and management of risks of production of biodiesel is constructed. The author's method of calculating the impact of the risk complex takes into account the limit values of the intervals of fuzzy quantities. To preserve soil fertility and reduce the corresponding risks, the proportion of rapeseed in growing areas should be at the limit of 17—18% (when also growing sunflower the upper limit is 12%), then all three analyzed farms can not only use their own land for rapeseed crops, but also, if necessary, rent the necessary plot, or, according to the results of the relevant analysis, its part. In some cases, farms even purchase some of the seeds needed to load the equipment. The results of calculations of the cost of production of biofuels showed that the increase in the cost for small and medium producers is not significant compared to large producers.

***Keywords**:* biofuels, biodiesel, risk management, agricultural enterprises, risk management, efficiency.

JEL Classification O13, Q42

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ЕКОНОМІКА ТА УПРАВЛІННЯ РИЗИКАМИ ВИРОБНИЦТВА БІОПАЛИВА В СІЛЬСЬКОМУ ГОСПОДАРСТВІ

Анотація. Розвиток ринку біопалива у світі має позитивну динаміку до зростання. Обґрунтування напрямів подальшого удосконалення методики управлінням виробництвом альтернативними видами палива відбувається з урахуванням політики зміни клімату та можливості зниження залежності від зовнішніх постачальників традиційних видів палива. Україна має сприятливі природно-кліматичні умови для розвитку виробництва нетрадиційних видів палива. Найбільш поширеними культурами, можливими для вирощування на українській території для цілей біопалива, є ріпак і кукурудза. Виходячи з матеріально-технічної бази і виробничих умов кращою сільськогосподарською культурою для культивування виступає ріпак. Тому об'єктом нашого дослідження було обрано виробництво біодизелю, що не вимагає суттєвих капітальних витрат з боку аграрних підприємств. Для цілей дослідження проведено групування ризиків за різними ознаками класифікації (операційні й виробничі; маркетингові; фінансові; юридичні й інфраструктурні; погодні; екологічні) і ваги їхнього впливу на результати функціонування аграрних підприємств. Побудовано структурну схему алгоритму автоматизованої оцінки впливу факторів ризику для розроблення основ аналізу та управління ризиками виробництва біодизелю. Наведена авторська методика розрахунків впливу комплексу ризиків ураховує граничні значення інтервалів нечітких величин. Для збереження родючості ґрунту і зменшення відповідних ризиків питома вага ріпаку в посівних площах повинна бути на межі 17—18 % (при вирощуванні господарствами ще й соняшнику — верхня межа 12 %), то всі три проаналізовані господарства можуть не тільки використовувати під посіви ріпаку власну землю, а й, за потреби, орендувати потрібну ділянку чи, за результатами відповідного аналізу, її частку. У деяких господарствах ідуть навіть на закупівлю частини насіння, потрібного для завантаження обладнання. Отримані результати розрахунків собівартості виробництва біопалива показали, що для малих і середніх виробників порівняно з великими виробниками не є значними.

Ключові слова: біопаливо, біодизель, управління ризиками, підприємства сільського господарства, управління ризиками, ефективність.

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Introduction. Biofuels are an alternative to traditional fuels. Developed countries of the world pay a lot of attention to the development of the biofuels sector, reducing dependence on external suppliers of traditional fuels and meeting the conditions for reducing CO_2 emissions. A necessary condition for the effective development of alternative fuels is the availability of sufficient raw materials, material and technical base, legislative initiative and regulatory support. These provisions are the starting point for the construction of production and processing infrastructure to ensure energy independence and security in the conditions of a turbulent environment.

Analysis of research and problem statement. Publications of Ukrainian and foreign scientists are devoted to the management of alternative fuels. Thus, in the studies of Kolosov O.Ie., Riabtsev H.L., Sivetskyi V.I., Sidorov D.E., Prystailov S.O. [1] the directions of increasing the efficiency of biofuel preparation are considered, the economic, technical and ecological aspects of bioethanol and biodiesel production are analyzed. In the work of Holub H.A., Kukharets S.M., Chuba V.V., Marus O.A. [2] the mechanical and technological bases of processes of production and use of biofuels in agroecosystems with the increased level of energy autonomy are presented. Shpychak OM, Bodnar OV, Pashko SO [3] proposed an economic model of the algorithm for determining the economic feasibility of processing rapeseed for biodiesel at the micro and macro levels depending on the market situation in a particular period of time. Marchetti J.M., Miguel V.U., Errazu A.F. [4] reviewed alternative technological methods that can be used for biodiesel production. Ryms M., Lewandowski W.M., Januszewicz K., Klugmann-Radziemska E., Ciunel K. [5] focused their attention on a more detailed presentation and description of the most popular biodiesel technologies today, as well as on the details of selected parameters and efficiency of units based on these technologies. Ito T., Sakurai Y., Kakuta Y., Sugano M., Hirano K. [6] proposed a scheme for the production of biodiesel from animal fat waste by pyrolysis. Havrysh V., Nitsenko V., Balezentis T., Streimikiene D. et al. [7—9] propose to use as an alternative fuel green methanol and biogas from crop residues from fields. Thus, the appropriate theoretical and methodological basis for this study has been developed.

The purpose of the article is to assess the efficiency of biofuel production in basic farms using the biodiesel as an example.

Unsolved aspects of the problem. Practical aspects of biodiesel production in changing conditions of functioning of agricultural enterprises and the choice of the most efficient scheme of its production.

Research results. The groups of risks inherent in the production of agricultural products and calculated for them by the method of weighted average of weight factors (degree) of risk are given in *Table 1*.

Table 1

Comparison of risk groups of agricultural production by weighted average value of weight factor (degree) of risk

Risk groups	Description of risk groups	The weighted average value of the weight factor (degree) of risk, calculated for the risk group
Operating, production	production, logistics, distribution	0.30
Marketing	prices, distribution, consumer problems	0.01
Financial	credit, tax, product profitability, poor financial planning, cost of consumables, raw materials, components, devaluation, inflation, world fuel prices, the risk of uneven cash flow	0.11
Legal, infrastructural	legal, personnel issues, environmental impact, political and legislative component, strategic, image, information	0.30
Weather	hail, storms, early frosts, too much or too little precipitation, etc	0.80
Ecological	environmental pollution (glycerin), reduced soil fertility, crop failure.	0.40

To the environmental risks inherent in the production of agricultural products in Ukraine, we add the risks specific to the cultivation of rapeseed. This crop, in particular, cannot be sown on the same growing areas more than once every five years. Because, even with the application of an appropriate, significant quantity of mineral fertilizers (150 kg / ha of nitrogen fertilizers, 60 kg / ha of phosphorus fertilizers and 120—130 kg / ha of potassium fertilizers) rapeseed will deplete the soil. Rapeseed diseases have become more common in recent years, and these diseases have not been observed in Ukraine before. This leads to a significant (almost 90%) increase in the weight (degree) of the entire environmental risk group.

There are other risks that correspond to the different groups listed in *Table 1*, but are characteristic of the production of biodiesel from rapeseed. For example, biodiesel has poorer energy performance than inorganic fuels due to its oxygen content. This creates certain problems. In addition, according to literature sources, emissions from the combustion of rapeseed fuel are more harmful than from inorganic fuels. In the production of biodiesel, substances that pollute the environment are created. The large specific amount of by-product — glycerin makes it difficult to sell and requires additional disposal costs. The shelf life of biodiesel is three months [3; 6; 10], so its production and storage for the future with the seasonal nature of raw material production is problematic. Logistical problems are also created by the impossibility of using some types of transport for transportation of biodiesel, in particular, pipeline. But these risks have both appropriate weight and ways to neutralize them.

After the stage of determining the list of risks available for each individual case, the values of risk factors (degree) of risk are calculated for them. The introduction of the concept of risk weight removes the issue of heterogeneity and unrepresentative data on different types of risks for enterprises in different regions, and, accordingly, on the different consequences of risks depending on their weight.

The use of fuzzy data does not always allow the use of a clear formulaic representation of analytical dependencies with them. Formulas and algorithms that use the representation of fuzzy variables as so-called triangular numbers, built on three significant points, are complex and cumbersome, difficult to analyze [1; 2; 7—9; 11].

The algorithmic implementation of fuzzy quantities is complicated by the fact that operations with defined non-negative fuzzy numbers require the use of different approaches than conventional operations with real numbers. In this case, the calculations should be performed not with the numerical values of the variables, but with the use of the limit values of the confidence intervals of fuzzy quantities. Then mathematical operations with the specified intervals allow the use of sets of real numbers. These real numbers are the limit values of the intervals of change of fuzzy quantities [4; 5; 11].

Therefore, for the convenience of analysis and simplification of the algorithm, triangular complexes are used, the arguments of which are the mentioned limit values of the intervals of fuzzy quantities. These complexes can be represented in General as $d_k = f(NPV_{min}, NPV_{med}, NPV_{max}, a)$. Namely, for our case:

$$d_1 = NPV_{\min} + a(NPV_{\text{med}} - NPV_{\min}); \quad (1)$$

$$d_2 = NPV_{\max} + a(NPV_{\text{med}} - NPV_{\max}); \quad (2)$$

$$d_3 = NPV_{\max} - NPV_{\min}; \quad (3)$$

$$d_4 = NPV_{\text{med}}/(NPV_{\text{med}} - NPV_{\min}). \quad (4)$$

Then the function of the weight (degree) of each risk for the project will be determined as follows [8; 9; 11]:

$$\gamma(a) = \{0 \; in \; case \; d_1 > 0; \; -d_1/(d_2 - d_1) \; \; in \; case \; d_1 \leq 0, \; d_2 \geq 0 \; 1 \; in \; case \; d_2 < 0 \}. \quad (5)$$

And, substituting the corresponding value of $\gamma(a)$ (according to the given expression) taking into account the designations of complexes (1) — (4) made by us, we will receive connection of a vector of risk of the project with values corresponding to values of criterion pure current or reduced values - $NPV_{\min}$, NPV_{med}, $NPV_{\max}$ which will be represented as real numbers.

As a result, we get

$$\vec{y} := (-NPV_{\min}/d_3) + (NPV_{\text{med}}/d_3) \; ln \ln \; d_4. \quad (6)$$

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The proposed algorithm for automating the assessment of the impact of risk factors and the development of a basis for risk analysis and management is presented in *Fig. 1*.

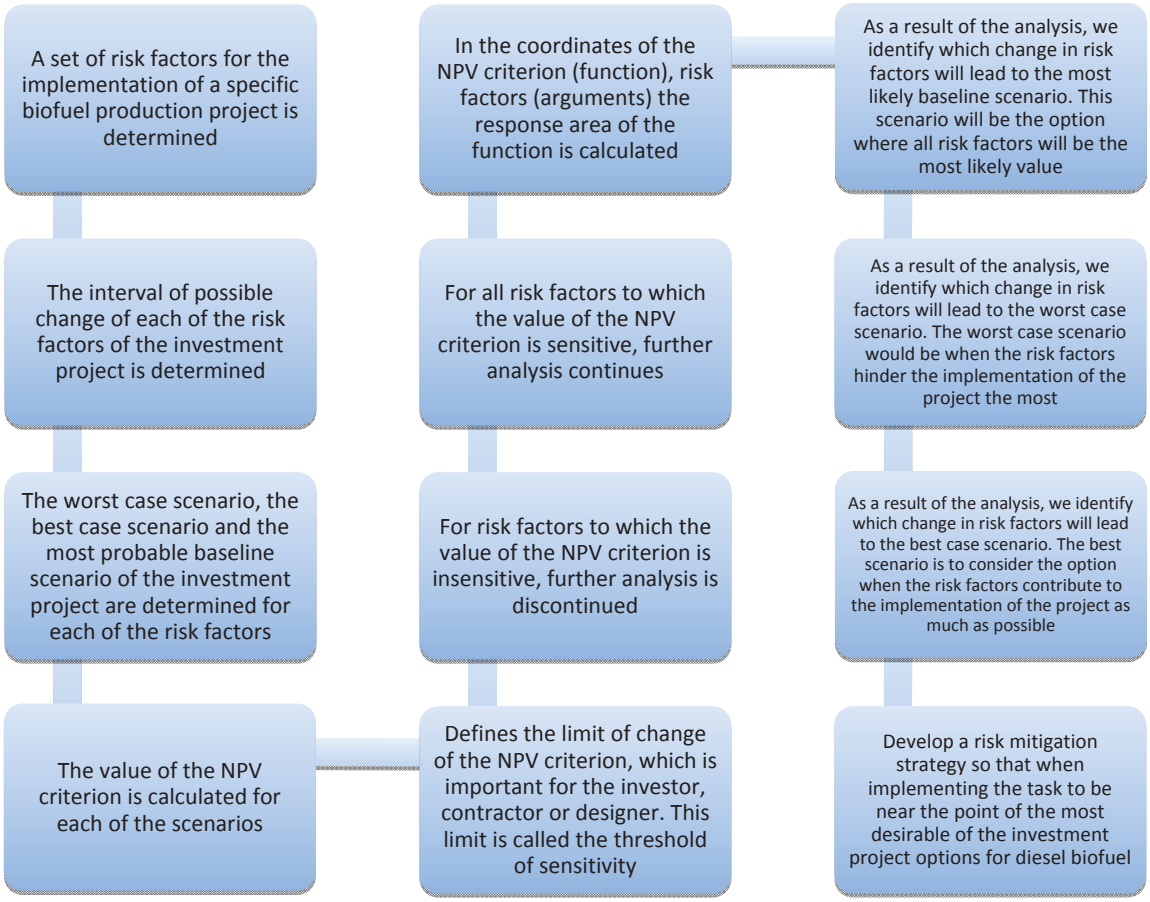

Fig. 1. **Block diagram of the algorithm for automated assessment of the impact of risk factors for the development of the basis of analysis and risk management**

The results of the analysis performed according to the developed mathematical algorithm become the substantiation of the business plan of the project of introduction of biofuel production.

According to the program developed on the basis of this algorithm using data [1; 2; 8; 12; 13] and the State Agency for Energy Efficiency and Energy Saving of Ukraine, the analysis of three manufacturers was conducted — one from Mykolaiv, Zhytomyr and Dnipropetrovsk regions (*Table 2*) (http://saee.gov.ua/vidnovlyuvana-energetika).

Table 2

Objects investigated using the developed algorithm

№	Producer	The name of the fuel	Regulatory document for products
1	Mykolaiv region, production cooperative	Biodiesel	TU U 24.1–2433016356–002: 2006
2	Zhytomyr region	Winter diesel fuel alternative B-30	SOU 24.14–37–561: 2007
3	limited liability company	Summer diesel fuel alternative B-30	TU U 24.6–31514949–010: 2010

The data used in the analysis are shown in *Table 3* and *4*.

Table 3

The cost of production of rapeseed per 1 ha for three farms

The name of the cost item	Enterprise 1			Enterprise 2			Enterprise 3		
	Amount	price, UAH	cost-total, UAH	Amount	price, UAH	cost-total, UAH	Amount	price, UAH	cost-total, UAH
Production costs of the farm for:									
seeds, kg	4.5	155.00	697.50	4.5	155.00	697.50	4.5	155.00	697.50
mineral fertilizers, kg									
nitroammophos	200	9.20	1840.00	200	9.20	1840.00	200	9.20	1840.00
ammonium nitrate	300	8.40	2520.00	300	8.40	2520.00	300	8.40	2520.00
Remedies, l									
insecticides	0.2	850.00	170.00	0.2	850.00	170.00	0.2	850.00	170.00
herbicides:									
Gallery Super, RK	0.35	3463.00	1212.05	0.35	3463.00	1212.05	0.35	3463.00	1212.05
Select120, k.e.	1.8	850.00	1530.00	1.8	850.00	1530.00	1.8	850.00	1530.00
Proponite 720, k.e.	3.0	416.00	1248.00	3.0	416.00	1248.00	3.0	416.00	1248.00
fungicides	0.6	702.00	421.20	0.6	702.00	421.20	0.6	702.00	421.20
Fuel, kg	48.5	28.27	1371.10	51.2	28.27	1447.42	49	28.27	1385.23
Inks			68.55			72.37			69.00
Repair			553.92			557.93			557.93
Total expenditures			1163.23			1171.65			1165.22
Amortization			339.45			342.01			338.10
Wages, people / hour	6.65	80.41	534.73	7.36	80.41	591.82	6.90	80.41	554.63
Yield, quintals / ha	20			28			25		
Land rent			2190.00			2190.00*			2190.00*
Purchase price of rapeseed for processing, UAH			9000*			9000*			9000*
Meal yield,%	58			58.1			58		
Yield of glycerin, kg / ton of seeds	68			68			68		
Total costs per 1 ha, UAH			15839.83			13821.94 16011.94**			13708.86 15898.86**
Production cost, UAH / ton			7919.92			4936.47 5718.62**			5483.74 6359.74**

* In fact — currently absent, but possible to maintain crop rotation.
** When renting land

Table 4

Operating costs required for the operation of biodiesel production equipment for three farms (basic option)

The name of the cost item	Enterprise 1	Enterprise 2	Enterprise 3
The content in rapeseed of low-drying oil with an iodine value of 94—112, %	44.6	45,0	40,1
Cost of methanol, UAH / ton of biodiesel	504.00	504.00	504.00
Methanol transportation costs, UAH / ton of biodiesel	28.3	57.23	32.4
Cost of caustic soda, UAH / ton of biodiesel	32.68 *	32.68 *	32.68
Costs of transportation of caustic soda, UAH / ton of biodiesel	11.2 *	19.0 *	12.4
Cost of sulfuric acid, UAH / ton of biodiesel	10.32 *	10.32*	10.32
Costs for transportation of sulfuric acid, UAH / ton of biodiesel	9.2 *	10.75*	9.6
Cost of electricity, UAH / ton of biodiesel	25.07	25.07	25.07
The cost of repair and maintenance of equipment, UAH / ton	12.41	5.7	6.9
Contingencies, UAH / ton of biodiesel	112.47	112.47	112.47
Staff salaries, UAH / ton of biodiesel	138.81	138.81	138.81
Single social security tax, UAH / ton of biodiesel	51.04	51.04	51.04
Transport and storage costs, UAH / ton of biodiesel	86.98	86.98	86.98
Depreciation, UAH / ton of biodiesel	81.24	72.58	74.8
The sale price of meal, UAH / ton	6400	7200	6900
Sales price of glycerin, UAH / kg	17	17	17
Coefficient of increase of fuel consumption at use of biodiesel	1.12	1.12	1.12
Operating costs, UAH / t of biodiesel	1084.2 1103.72*	1063.95 1136.7*	1122.54

* If necessary.

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Since, in order to preserve soil fertility and reduce the corresponding risks, the share of rapeseed in growing areas should be at the limit of 17—18% (when also growing sunflower the upper limit is 12%), all three analyzed farms can not only use their own land for rapeseed, but also, if necessary, rent the necessary plot, or, according to the results of the relevant analysis, its part. In some cases, farms even purchase some part of the seeds necessary to load the equipment (the purchase price of the seed and the cost of renting the land are given in the table).

The results of the calculation according to the data [14, 15] are given line by line in *Table 5* (enterprises are listed in the table in a manner similar to *Table 2*).

Table 5

The results of the calculation of the criterion of the net present value of three technological schemes of biodiesel production for three farms, thousand UAH

№	NPV_{min}			NPV_{max}			NPV_{med}		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Enterprise 1	1021	1012	1152	6279	6313	6676	3653	3207	3915
Enterprise 2	1031	1227	1122	5523	5894	6955	3274	3382	4036
Enterprise 3	1014	1118	1146	5352	5642	5569	3183	3457	3359

Post-scenario results of the analysis of three possible technological schemes of biodiesel production are given in the corresponding columns of *Table 5*. The numbers of these schemes are given in *Table 5* in the second line above. The first in number is a cyclic scheme of production with the use of catalysts. The second in number is the catalyst-free cyclic scheme. The third scheme is multi-reactor continuous.

According to the result of the analysis, in the case of a non-aggressive risk management option, a multi-reactor continuous scheme is the choice for a production cooperative in Mykolayiv region, the third scheme is preferable for a limited liability company in Zhytomyr region also, a cyclic production scheme using catalysts is the choice for a limited liability company in Dnipropetrovsk region.

The method of avoiding and reducing risk is known [1; 2; 4; 7; 14; 15], it is: refusal of risky actions, decision-making in conditions of uncertainty or low probability of success with significant losses, work to prevent risk and reduce possible losses.

The ratio of the cost of production of a ton of biofuel for a farm with a growing area of rapeseed ~ 100 ha and a farm with a growing area of rapeseed ~ 1000 ha for three regions of Ukraine — Mykolayiv, Zhytomyr and Dnipropetrovsk (in calculations for 0.4 cubic meter unit and 2 cubic meter unit) on average with a small deviation by region within the statistical error was 10.6%. This, in our opinion, proves that the increase in the cost of biofuel production for small and medium-sized producers compared to large producers is not significant. However, for small and medium-sized producers, the significant logistical risks of rapeseed supply are eliminated, and part of the environmental risks associated with crop rotation disturbances are almost completely eliminated — the indicator of the degree of this risk for small and medium-sized farms is estimated to be insignificant 0.05. This is another argument in favor of using the proposed scheme of organization of biodiesel production in Ukraine at small enterprises located mainly in villages and district centers [16—19]. Undoubtedly, this conclusion is not an absolute denial of the use, under certain conditions considering the inherent risks, of other options for biodiesel production.

The recommendation of use is the formation of closed-loop production, use and processing of secondary resources in the manufacturing of agricultural products.

Conclusion. According to the results of the study, it is proposed to use the risk grouping technique for biodiesel production. The structural scheme of the algorithm of the automated estimation of influence of risk factors for development of bases of the analysis and management of risks of production of biodiesel is constructed. The author's method of calculating the impact of the risk complex takes into account the limit values of the intervals of fuzzy quantities. It is determined that in order to preserve soil fertility and reduce the corresponding risks, the share of rapeseed in growing areas should be at the limit of 17—18%. The results of calculations showed that the

increase in the cost of biofuel production for small and medium producers is not significant compared to large producers.

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