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MATHEMATICAL RISK ASSESSMENT MODEL FOR BIODIESEL PRODUCTION PROJECTS IN UKRAINE AGRICULTURE

Abstract. One of the trends in the development of the market of alternative motor fuels is the production and use of biofuels, biodiesel in particular. Biodiesel which is used by domestic farmers is mainly self-produced. The current situation is related, first of all, to the lack of a single standard (regulation) for biodiesel production technology and is not enshrined in any legal act in Ukraine. In the conditions of the market functioning, agricultural producers face various risk factors, in particular, instability of prices for fuels and lubricants, monopolization of certain regions or market segments by traders, low quality of fuel, etc. Conditions of biodiesel production, as well as other economic activities, usually require the creation or involvement of labor, financial and material resources, which also affects the change in the level of risk. These problems can be solved by adapting and improving the existing mathematical apparatus to risk assessment for biodiesel production projects by agricultural enterprises. The main legal act that allows to determine and assess the level of risk is the state standard of Ukraine «Risk Management. Methods of general risk assessment», which served as the methodological foundation of the study. We propose to use three main technological schemes of biodiesel production, namely: cyclic scheme of production with the use of catalysts; non-catalytic cyclic circuit and multi-reactor continuous circuit scheme. In order to analyze each of these schemes, it is proposed to analyze the feasibility of investment in terms of their effectiveness and tie-in to the risks of introducing innovative technologies. The developed methodology provides a substantiation for the choice of technological option for biodiesel production. An algorithm for calculating risks has been proposed for the introduction of biodiesel production, the preparation of business plans and the assessment of criticality of possible losses for the production. The use of methods of vector algebra and fuzzy logic in the formation of the mathematical model makes it possible to estimate the probability indicators of each risk.

***Keywords*:** biodiesel, risks, mathematical model, agriculture, risk assessment, risk assessment methods.

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МАТЕМАТИЧНА МОДЕЛЬ ОЦІНКИ РИЗИКІВ ДЛЯ ПРОЄКТІВ ВИРОБНИЦТВА БІОДИЗЕЛЮ В СІЛЬСЬКОМУ ГОСПОДАРСТВІ УКРАЇНИ

Анотація. Одним із трендів розвитку ринку альтернативного моторного пального є виробництво і використання біопального, зокрема біодизелю. Біодизель вітчизняні аграрії використовують в основному власного виробництва. Зазначена ситуація стосується, перш за все, відсутності єдиного стандарту (нормативу) на технологію виробництва біодизелю й не закріплена жодним нормативно-правовим актом в Україні. В умовах функціонування ринку сільськогосподарські виробники зіштовхуються з різними чинниками ризику, зокрема нестабільність цін на пально-мастильні матеріали, монополізація окремих регіонів чи сегментів ринку трейдерами, низька якість пального тощо. Умови виробництва біодизелю, зазвичай, як й інші види економічної діяльності, потребують створення чи залучення трудових, фінансових і матеріальних ресурсів, що також впливає на зміну рівня ризику. Зазначені проблеми можна розв’язати шляхом пристосування й удосконалення чинного математичного апарату до оцінки ризиків для проєктів виробництва біодизелю сільськогосподарськими підприємствами. Основним нормативно-правовим актом, що дає можливість визначити та оцінити рівень ризику, є державний стандарт України «Керування ризиком. Методи загального оцінювання ризику», який слугував методологічним фундаментом проведеного дослідження. Ми запропонували використовувати три основні технологічні схеми виробництва біодизелю, а саме: циклічна схема виробництва із застосуванням каталізаторів; безкаталізаторна циклічна схема і багатореакторна безперервна схема. З метою аналізу кожної з наведених схем пропонуємо проводити аналіз доцільності здійснення інвестицій за рівнем їхньої ефективності та прив’язкою до ризиків упровадження інноваційних технологій. Розроблена методика передбачає обґрунтування вибору технологічного варіанта виробництва біодизелю. Для впровадження виробництва біодизелю, формування бізнес-планів, оцінки критичності для виробництва можливих збитків запропоновано алгоритм розрахунку ризиків. Використання методів векторної алгебри і нечіткої логіки при формуванні математичної моделі робить можливим оцінку вірогідностних покажчиків кожного ризику.

Ключові слова: біодизель, ризики, математична модель, сільське господарство, оцінка ризиків, методи оцінки ризиків.

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Introduction. Biodiesel in many countries around the world, including the EU and Ukraine, is one of the alternative types of transport fuel. Unlike other countries, domestic agricultural enterprises are engaged in the production of biodiesel solely to meet their own production needs, without focusing on market needs.

To reduce the risks of critical dependence on fuel imports, decisions have been repeatedly made to increase biofuel production, including that of biodiesel. It was planned to build 20 plants with an annual production capacity of 5000 tons to 100000 tons of diesel biofuel. The construction of each such plant required the creation of infrastructure, transport hubs, elevators, agro-technical associations for the cultivation of raw materials with a total cost of up to 200 million euros. The plants had to organize the supply of raw materials from a distance of more than 150 kilometers, to compensate for the lack of their own resources. Lack of raw materials for biodiesel is not only a Ukrainian problem. The capacities of European biodiesel producers are not used to the full because they lack raw materials. The creation of a powerful Ukrainian biodiesel production will limit the capabilities of European producers, as it will reduce the supply of the necessary raw materials from Ukraine. Another factor against the construction of high-capacity plants in Ukraine is the need to sell a large amount of production waste, in particular, rapeseed meal. The sale of the large amount of production waste will be unprofitable due to significant transportation costs.

The situation has changed dramatically with the adoption of the law «On Amendments to the Budget Code of Ukraine on the reform of inter-budgetary relations» (since 2015). According to this law, territorial communities must take care of their own income. If the community does not take control of its own income or does not introduce incentives for all types of business in its territory, its budget opportunities will be reduced in favor of more successful communities. So relatively small budget communities, i.e. rural ones, will be the most susceptible to success or failure. But it is these communities that have the resources — labor, raw materials, which will allow them to make a significant breakthrough. One of such opportunities is the production of biodiesel.

Analysis of research and problem statement. In the state standard of Ukraine «Risk management. Methods of general risk assessment» [1] in paragraph 6.3 «Availability of resources and opportunities that may influence the choice of methods of general risk assessment» are defined. This paragraph explicitly indicates the actual inability for each of the risk factors listed in the standard not only to take into account, but at least to define with arguments and proofs a list of risks and their limitations for specific real circumstances.

Attempts to accelerate the spread of risk assessment methods, which have proven their practical usefulness for certain sectors of the economy, their copying in other sectors have often been accompanied by failure, as evidenced by studies [2—6]. Transferring even the best solutions, technologies and production schemes from one condition to another cannot guarantee their success. In our opinion, this is due to the fact that different industries do not have completely similar initial conditions, the same set of risks and assessment of their degree, and hence-equally successful decision-making measures to prevent these risks using standard management schemes.

It is impossible to take into account all the factors influencing this process for each implementation of a new technology [7—10]. Some risk factors may not be analyzed at all. The decisive risk factors for the project are often not analyzed, such as the structure and experience of traditional farming in the region, social and family ties of performers, their level of education and general technical training, mentality of management and employees, etc. For example, with regard to the latter factor, it is extremely important to know whether ethyl alcohol can be used as a solvent for the implementation of diesel biofuel technology — the so-called non-catalytic cyclic scheme. On the one hand, this relatively cheap solvent is not an expensive and rare chemical compound, its stocks can always be renewed, on the other hand, there is a question whether its excessive losses will lead to a violation of technology and labor discipline.

Therefore, the aim of our study is to introduce such an algorithm for estimating these factors, the results of which would become the analytical basis of business plans, would introduce effective decision-making systems and optimal sets of management actions for successful implementation of new technologies for small and medium businesses in Ukraine.

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The purpose of the article is to substantiate the choice of technological variant of biofuel production and to develop a mathematical model for assessing the risks of investing in such production. The mathematical model should link traditional assessments of the effectiveness of investment with the risks of innovation.

Unsolved aspects of the problem. The existing mathematical apparatus is not perfect to solve these problems before our study. Therefore, the mathematical model of risk assessment for biodiesel production projects in the existing economic conditions needs to be improved.

Research results. Let's consider the three main technological schemes of biodiesel production. The first of them is a cyclic scheme of production with the use of catalysts. The technological process, according to this scheme, requires simple and cheap equipment, the requirements for the quality of raw materials are low. But, on the other hand, the share of labor costs per liter of biodiesel and the time of one technological cycle is relatively high.

Another method of biodiesel production is the so-called catalyst-free cyclic scheme. This method requires the use of a solvent. The more efficient the solvent is, the more efficient is the extraction. But the use of an effective solvent also involves more stringent equipment requirements. In addition, the use of solvent complicates the production scheme, additional equipment is required and becomes more expensive. This method requires the use of higher quality raw materials than the previous one.

The third scheme is the so-called multi-reactor continuous which entails harsh physical conditions of extraction, high pressure and reaction temperature. Equipment becomes even more expensive and more complex. The production process is continuous, the duration of the technological cycle is short, the yield of essential oils is high.

Obviously, these three schemes are not competitive. Each scheme is needed for a certain type of production and each will find its consumer and there is no need to analyze the competitiveness of each of them. The point is how to choose the right scheme for a specific consumer?

Let's develop an algorithm of economic analysis to substantiate the choice of a specific scheme of production. This algorithm must be convincing for the business owner or investor, to become a leading tool for the introduction of new technologies. It should be borne in mind that when the program of biodiesel implementation does not serve narrow corporate purposes, but, for example, will serve the interests of the community, in Ukraine it is possible to get investment money from international organizations for this program. In this case, the algorithm of economic analysis must be convincing for the international investor.

Many international programs, US and EU funds are engaged into decentralization in Ukraine today. They have founded many projects, in particular, DOBRE, PULS, U-LEAD [11; 12]. However, one needs to assess one's own capabilities and weigh the risks to start working with them.

The main lever of the analysis of expediency of investments is an estimation of their efficiency. One of the methods of this is the method of calculating the net present value or present worth. As it is *Net present value* in English, the standard abbreviation is *NPV* [13]. As it is known, *NPV* is calculated by the formula:

$$NPV = \sum_{t=0}^{n} \frac{NCV_t}{(1+R)^t}, \qquad (1)$$

where in the numerator the value NCV_t is net cash flow during the *t*-th interval of the planning period *n*; *R* is a discount rate, taking into account the risks; *t* is the ordinal number of the planning interval, provided that the value of *t* at the beginning of the project equals zero.

But this formula needs to be changed to be used in a broader context.

First, the biofuel project will require initial investment. Let's denote the initial investment by the common abbreviation *I*. Secondly, at the end of the project life cycle there will be equipment that will have a certain value. Denote the liquidation value of equipment as *RC*.

Then formula (1) should be modified as follows:

$$NPV = -I + \sum_{t=0}^{n} \frac{NCV_t}{(1+i)^t} + \frac{RC}{(1+i)^{n+1}}. \quad (2)$$

But, as it was already mentioned, the biofuel project will be at risk throughout its life cycle. These risks, obviously, can be different for different situations and different projects. In our opinion, the statistical method should be used to assess risks. To do this, we determine the influence of each of the risk factors on the value of the criterion of net present value.

To estimate a risky event, we use the methods of vector algebra.

We use the above-mentioned mathematical methods of risk analysis [14; 15] and introduce the vector function of risk assessment:

$$\vec{\vartheta} := \varphi(P, \vec{\tau}), \quad (3)$$

where $\vec{\vartheta}$: is the risk assessment vector, it can be represented by a linear matrix; P is the value of the probability of the corresponding risk factor; $\vec{\tau}$ is a vector of consequences of the specified risk.

It should be borne in mind how the consequences of the defined risk may be different, depending on its degree.

After determining the definite or approximate limit values of each of the set $i = 1...k$ parameters ω_i, on which it depends in the probability interval of its occurrence (obviously, on the one hand, limited by the specified limit values of k parameters, on the other to $-\infty$), the value of risk is calculated according to the normal distribution law as an integral quantity:

$$\vec{\vartheta} := \int_1^{\omega_i} \varphi(\vec{\tau}) d\tau = \frac{\int_1^{\omega_i} exp\left(-\frac{\Delta\tau^2}{2{\sigma_x}^2}\right) d\tau}{\sigma_x \sqrt{2\pi\tau}}, \quad (4)$$

where $\Delta\tau$ is the difference between the current value of τ and its weighted average value; σ_x is the variance of the value of the risk assessment vector.

Methods of correlation-regression analysis assess the significance of the impact on the outcome of each of the probable risks.

To assess the significance of the impact of risk, in order to remove insignificant risks, we used the algorithm of generalized OLS (the least square method) estimates [16; 17]. When using this algorithm there was a problem of estimating the degree of autocorrelation of errors of variable risks at the interval of their calculation. This required the development of a separate computer program.

To form the algorithm, the factors influencing the risk should be divided into internal, depending on the community that decides to introduce diesel biofuel production or the owner-consumer of the loan, and external factors that do not depend on the community or the owner of the equipment. Then it is advisable to determine the risk vector by the formula:

$$\vec{y} := f(\vec{x}, \vec{z}), \quad (5)$$

where $\vec{y}$ is the vector of the corresponding risk; $\vec{x}$ vector n of internal parameters of the specified risk; $\vec{z}$ is the vector m of external factors.

Obviously, most often, the vectors $\vec{x}, \vec{z}$ — are linear matrices of the corresponding scalar quantities. We use the parameter a to indicate the weight (degree) of each risk for the project among the entire list of probable risks for the project.

In this case, as it is known, the weight (degree) of each risk is limited to the range:

$$a \in (0, 1). \quad (6)$$

When finding the criterion of present worth or net present value *NPV* for agricultural production, it is characteristic that the existing risks change within certain limits of numerical values and their change is subject to interval-symmetric estimation or, with a slight error, these risks can be estimated as interval-symmetric values.

A characteristic feature in finding the value of the *NPV* criterion is that the uncertainty in considering the risks is significant. In this case, it is advisable to use methods of fuzzy logic [18].

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When using fuzzy logic methods, the vector of the corresponding risk [18] can be represented as:

$$\vec{y} := \int_0^b \gamma(a)da, \quad (7)$$

where $\gamma(a)$ is weight (degree) function of the corresponding risk.

According to the representations, for the upper limit of integration let's use a simplex, which is based on the so-called fuzzy triangular number *b*.

The specified number is based on three significant points ($b_{\min}, b_{av}, b_{\max}$). The use of these significant points is not new in the economic representation of fuzzy numbers. This technique is an analogy which is widely used in economics, the so-called pessimistic, average and optimistic variants of the studied events.

This approach allows to move from probable events described by parameters to expected numbers and events. In our case, an example of this is the representation of the simplex ***b*** as a function of $b = f(NPV_{\min}, NPV_{av}, NPV_{\max})$ namely, for our case according to the recommendations [18]:

$$b = \frac{NPV_{\min}}{(NPV_{\max} - NPV_{av})}, \quad (8)$$

where $NPV_{\min}$ is the minimum value of the criterion of net present value in the interval of its change under the influence of the corresponding risks; NPV_{av} is the expected average value of the criterion of the net present value; $NPV_{\max}$ is the maximum value of the criterion of net present value in the interval of its change under the influence of the relevant set of risks [8; 18].

Conclusion. A method of substantiation of the choice of technological variant of biofuel production has been developed. It is stated that for such production it would be better to use low-capacity productions close to rural fuel consumers and raw material suppliers.

An algorithm for calculating risks has been proposed for the introduction of biofuel production, the preparation of business plans and the assessment of criticality of possible losses for the production.

The developed mathematical algorithm of calculation connects the traditional estimation of efficiency applying the criterion of the net present value with the risks of introducing innovative technology. The use of the methods of vector algebra and fuzzy logic in the formation of the mathematical model makes it possible to estimate the probability of each risk indicator.

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