Всеукраїнський науково-технічний журнал

All-Ukrainian Scientific & Technical Journal

ISSN 2520-6168 (Print)

DOI:10.37128/2520-6168-2024-4

№4 (127)

2024

Machinery
Energetics
Transport
of Agribusiness

ТЕХНІКА
ЕНЕРГЕТИКА
ТРАНСПОРТ АПК

Науковий журнал

ТЕХНІКА, ЕНЕРГЕТИКА, ТРАНСПОРТ АПК

№ 4 (127) / 2024

м. Вінниця – 2024

Scientific Journal

Engineering, Energy, Transport AIC

Vol 127, № 4 / 2024

Vinnytsia – 2024

Журнал науково-виробничого та навчального спрямування
Видавець: Вінницький національний аграрний університет

ТЕХНІКА, ЕНЕРГЕТИКА, ТРАНСПОРТ АПК

Заснований у 1997 році під назвою «Вісник Вінницького державного сільськогосподарського інституту».
Правонаступник видання: Збірник наукових праць Вінницького національного аграрного університету. Серія: Технічні науки.
Свідоцтво про державну реєстрацію засобів масової інформації
КВ № 16644–5116 ПР від 30.04.2010 р.

Науковий журнал «Техніка, енергетика, транспорт АПК» / Редколегія: Токарчук О.А. (головний редактор) та інші. Вінниця, 2024. № 4 (127). С. 1-99.

Друкується за рішенням Вченої ради Вінницького національного аграрного університету (протокол № 6 від 24.12.2024 р.)

Свідоцтво про державну реєстрацію засобів масової інформації №21906-11806 Р від 12.03.2016р.

Журнал «Техніка, енергетика, транспорт АПК» включено до переліку наукових фахових видань України з технічних наук (Категорія «Б», Наказ Міністерства освіти і науки України від 02.07.2020 року №886).

Згідно рішення Національної ради України з питань телебачення та радіомовлення від 25.04.2024 р. №1337 науковому журналу «Техніка, енергетика, транспорт АПК» присвоєно ідентифікатор медіа R30-05173.

Журналу «Техніка, енергетика, транспорт АПК» присвоєно ідентифікатор цифрового об'єкта (Digital Object Identifier – DOI).

Журнал включений до міжнародних наукометричних баз і каталогів наукових праць:

- ***Index Copernicus Value з 2018 року, сайт: https://journals.indexcopernicus.com/search/details?id=47074;***
- ***Національної бібліотеки України ім. В.І. Вернадського, сайт: http://www.irbis-nbuv.gov.ua;***
- ***Google Академія, сайт: https://scholar.google.com.ua/citations?user=A5layLAAAAAJ&hl=uk;***
- ***CrossRef, сайт: https://www.crossref.org.***

відповідальний секретар редакції – **Полєвода Ю.А.** к.т.н., доцент,
літературний редактор української та іноземних мов – **Погранична Н.М.,**
Адреса редакції: 21008, Вінниця, вул. Сонячна 3, Вінницький національний аграрний університет, тел. (0432) 46–00–03
Сайт журналу: http://tetapk.vsau.org/ **Електронна адреса: pophv@ukr.net**

ENGINEERING, ENERGY, TRANSPORT AIC

Journal of scientific, industrial and educational direction
Publisher: Vinnytsia National Agrarian University

It was founded in 1997 under the name "Bulletin of the Vinnytsia State Agricultural Institute".
Successor publication: Collection of Scientific Works of the Vinnytsia National Agrarian University. Series: Technical sciences.
Certificate of state registration of mass media
KV No. 16644–5116 PR dated 04/30/2010

Scientific journal "Technology, Energy, Transport AIC" / Editorial board: Tokarchuk O.A. (chief editor) and others. Vinnytsia, 2024. Vol. 127, № 4, P. 1-99.

Printed by decision of the Academic Council of the Vinnytsia National Agrarian University (protocol №. 6 dated December 24, 2024)

Certificate of state registration of mass media No. 21906-11806 R dated March 12, 2016.

The journal "Technology, Energy, Transport AIC" is included in the list of technical scientific publications of Ukraine (Category "B", Order of the Ministry of Education and Science of Ukraine dated 07.02.2020 No. 886).

According to the decision of the National Council of Ukraine on Television and Radio Broadcasting dated 04/25/2024 No. 1337, the scientific journal " Technology, Energy, Transport AIC " was assigned the media identifier R30-05173.

The journal " Technology, Energy, Transport AIC " has been assigned a digital object identifier (DOI).

The journal is included in the international scientometric bases and catalogs of scientific works:

- Index Copernicus Value since 2018, website: https://journals.indexcopernicus.com/search/details?id=47074;

- National Library of Ukraine named after V.I. Vernadskyi, website: http://www.irbis-nbuv.gov.ua;

- Google Academy, website: https://scholar.google.com.ua/citations?user=A5layLAAAAAJ&hl=uk;

- CrossRef, website: https://www.crossref.org.

editor-in-chief – ***Yurii POLIEVODA***, Candidate of Technical Sciences, Associate Professor,
literary editor of Ukrainian and foreign languages – ***Natalia POGRANICHNA***
Address of the editorial office: 21008, Vinnytsia, str. Sonyakna 3, Vinnytsia National Agrarian University, tel. (0432)46-00-03
The magazine's website: *http://tetapk.vsau.org/* **E-mail address:** *pophv@ukr.net*

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UDC 631.372
DOI: 10.37128/2520-6168-2024-4-6

COMPREHENSIVE STUDY OF THE FEASIBILITY CRITERIA FOR BIODIESEL PRODUCTION BASED ON FARMING ENTERPRISES

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The relevance of biodiesel fuel production based on farm enterprises is highlighted. A cost analysis for biodiesel fuel production has been conducted, demonstrating the feasibility of manufacturing it using self-produced raw materials obtained from oilseed crops grown on farms. To assess the efficiency and feasibility of oilseed production and its derived products, three business models of implementation are proposed: rapeseed cultivation and sale of its seeds at market prices, single-stage processing of rapeseed seeds into edible oil, and two-stage processing of rapeseed seeds into biodiesel fuel. Economic indicators such as production cost, profit, profitability, and margin are calculated depending on the chosen model, based on which the feasibility of rapeseed realization through one of the three pathways is justified. A strategy for implementing rapeseed or its products, including biodiesel fuel, is proposed, prioritizing the business model that maximizes profit. Conditions for applying each business model are also considered, not only from the perspective of maximizing profit but also for parallel use of two or all three implementation models of rapeseed seeds. Graphical dependencies of profitability and marginality on profit for all three models are constructed, delineating zones of feasibility for applying a particular business model depending on market prices for the respective products. The feasibility of the two-stage processing of rapeseed seeds into biodiesel fuel, which can compete with petroleum-based diesel fuel in the liquid fuel market, has been demonstrated. This scientific paper presents the results of the initiative research project 0122U002187.

To further enhance the practical applicability of the proposed models, the environmental benefits of biodiesel production were evaluated, emphasizing its role in reducing greenhouse gas emissions and promoting sustainable agricultural practices. Additionally, the on rural development was analyzed, demonstrating how biodiesel production can foster job creation, energy independence, and the diversification of income sources for farming enterprises.

Key words: *biodiesel fuel, rapeseed oil, rapeseed seeds, two-stage processing, production cost, single-stage processing, profit, profitability, margin.*

F. 47. Fig. 2. Tabl. 1. Ref. 15.

1. Problem formulation

The production of biofuels based on farm enterprises in Ukraine represents a promising prospect, contributing to the energy independence of agricultural production. An example of this is the experience of neighboring countries, particularly farmers in Poland [1].

A wealth of scientific literature provides a basis for the production and use of biodiesel fuel, as detailed in the review presented in [2]. Additionally, studies on the economic efficiency of biodiesel fuel production, such as those in [3, 4], demonstrate unequivocal economic benefits. Thus, there is both scientific potential and economic justification for biodiesel fuel production.

However, the efficiency of utilizing biofuels for self-consumption or custom production by agricultural producers using their own raw materials remains unresolved.

As of today, the production of biodiesel fuel on the basis of farms remains a promising direction of development, especially in the conditions of the energy crisis and the increase in prices for fossil fuels. The main advantage of this direction is the possibility of using locally grown raw materials, for example, rapeseed, which significantly reduces logistics costs and ensures the energy independence of farms.

An analysis of market conditions shows that prices for biodiesel and rapeseed oil are increasing due to increased demand for environmentally friendly fuels. At the same time, there is competition with traditional

types of fuel, in particular diesel, but models of two-stage rapeseed processing show economic feasibility even in the presence of an excise tax.

The use of three business models – rapeseed cultivation, one-stage processing into oil, and two-stage processing into biodiesel – allows for adaptation to dynamic market conditions. For example, when the price of biodiesel is in the range from UAH 46.81 to 49.44/l, the two-stage processing model is the most appropriate. If the price decreases, but rapeseed oil is sold above UAH 34.82/l, it is rational to switch to the one-stage processing model. In case of unfavorable conditions for both models, the sale of rapeseed remains a stable option.

The developed strategy emphasizes the importance of a flexible approach for farms, which allows you to quickly respond to changes in market conditions, ensure income stability and minimize risks. At the moment, it is important to take into account regulatory aspects (excise taxes, government support), market availability and environmental benefits of biodiesel, which can contribute to increasing its competitiveness.

2. Analysis of recent research and publications

In the study [4], the economic efficiency of biodiesel fuel production was thoroughly analyzed through two-stage processing of rapeseed or single-stage processing of rapeseed oil. However, market prices for both rapeseed and rapeseed oil were used to calculate the cost of raw materials. The scientific interest within this work lies in calculating the economic efficiency of producing biodiesel fuel from self-sourced raw materials at their production cost.

To perform such a calculation, input data regarding the cost of raw materials for biofuel production are required. In our case, this refers to the cost of rapeseed cultivation. Current data on this matter are provided in an article on the "Main Agronomists' Website" [5], according to which the upper limit of rapeseed cultivation cost this year is 23,000 UAH/ha with a yield of 3.3 t/ha. Recalculated per ton of harvested product, this equals 23000/3,3 = 6970 UAH/t.

Using the methodology described in [4], the production cost C indicator for two-stage processing of rapeseed (Stage I – processing oilseeds to produce vegetable oil; Stage II – processing vegetable oil into biodiesel fuel) is determined as follows:

$$\mathrm{C} = \frac{P_{rm} \cdot \rho_B}{m_B \cdot k_{pc}}, \quad (1)$$

where P_{rm} – market price of raw materials, UAH/t; ρ_B – density of biofuel, kg/m³; m_B – biofuel yield from 1 ton of raw materials in two-stage processing, kg/t;

k_{pc} – production cost coefficient for biodiesel fuel production.

To determine the production cost of biodiesel fuel from self-sourced raw materials $\mathrm{C}_{ssrm\mathrm{II}}$, formula (1) can be rewritten as:

$$\mathrm{C}_{ssrm\mathrm{II}} = \frac{\mathrm{C}_{rm} \cdot \rho_B}{m_B \cdot k_{pc}}, \quad (2)$$

where C_{rm} – the cost of raw material cultivation, C_{rm} = 6970 UAH/t [5]; ρ_B = 880 kg/m³ = $880 \cdot 10^{-3}$ kg/l [6]; $m_B = 450$ kg/t [3]; $k_{pc} = 0{,}7$ [4].

Substituting the values into formula (2), we get:

$$\mathrm{C}_{ssrm\mathrm{II}} = \frac{\mathrm{C}_{rm} \cdot \rho_B}{m_B \cdot k_{pc}} = \frac{6970 \cdot 880 \cdot 10^{-3}}{450 \cdot 0{,}7} = 19{,}47 \text{ UAH/l}.$$

According to the calculation methodology [4], we calculate the added value of the first stage V_{Arm1} of two-stage processing:

$$V_{Arm1} = \frac{P_{rm1} \cdot m_m \cdot \rho_B}{m_B}, \quad (3)$$

where P_{rm1} – the price of the by-product from the first stage of processing, according to [7], for rapeseed meal, P_{rm1} = 10000 UAH/t; m_m – yield of obtained meal from 1 ton of oilseed, for rapeseed m_m = 550 kg/t;

$$V_{Arm1} = \frac{P_{rm1} \cdot m_m \cdot \rho_B}{m_B} = \frac{10000 \cdot 550 \cdot 880 \cdot 10^{-6}}{450} = 10{,}76 \text{ UAH/l}.$$

The next step is to determine the cost price, taking into account the added value from the first stage of processing [4]:

$$\mathrm{C}_1 = \mathrm{C} - V_{Arp1}, \quad (4)$$

$$\mathrm{C}_1 = \mathrm{C} - V_{Arm1} = 19{,}47 - 10{,}76 = 8{,}71 \text{ UAH/l}.$$

The added value generated during the second stage of oilseed processing is calculated using the methodology in [4]:

$$V_{Arg2} = \frac{P_{rg2} \cdot V \cdot \rho_B}{m_B}, \quad (5)$$

where P_{rg2} – is the price of the by-product from the second stage of oilseed processing – raw unrefined glycerine;V – is the yield of glycerine obtained per 1 ton of oilseeds, measured in liters per ton.

To determine the added value, formula (5) is slightly modified, considering the price of the by-product (glycerine) not per liter but per kilogram, which is currently P_{rg2} = 27 UAH/kg in the market [8]:

$$V_{Arg2} = \frac{P_{rg2} \cdot V \cdot \rho_B \cdot \rho_{gl}}{m_B}, \quad (6)$$

where V=45 l/t; ρ_{gl} – is the density of glycerine, ρ_{gl} = 1261 kg/m^3 = 1261 kg/l [9].

Then, substituting the values into formula (6), we have:

$$V_{Arg2} = \frac{P_{rg2} \cdot V \cdot \rho_B \cdot \rho_{gl}}{m_B} = \frac{27 \cdot 45 \cdot 1261 \cdot 880 \cdot 10^{-6}}{450} = 3{,}00 \text{ UAH/l}.$$

The production cost of biodiesel fuel from oilseeds after the second stage of processing [4]:

$$\mathrm{C}_2 = \mathrm{C}_1 - V_{Arg2}, \quad (7)$$

$$\mathrm{C}_2 = \mathrm{C}_1 - V_{Arg2} = 8{,}71 - 3{,}00 = 5{,}71 \frac{\text{UAH}}{\text{l}}.$$

Taking into account the excise tax, the production cost of fuel made from own raw materials is calculated as:

$$\mathrm{C}_3 = \mathrm{C}_2 + \mathrm{E}, \quad (8)$$

where E – is the excise tax, E = 106 € per 1000 liters [10], which, according to the NBU exchange rate [11] as of today, equals A = 4,64 UAH/l.

Substituting the values into formula (8), we obtain the final production cost of biodiesel fuel made from rapeseed based on its cultivation cost:

$$\mathrm{C}_3 = \mathrm{C}_2 + \mathrm{A} = 5{,}71 + 4{,}64 = 10{,}35 \text{ UAH/l}.$$

To compare the price of biofuel with the market price, we use the formula provided in the cost calculation methodology [4]:

$$P_{Bmax} = \frac{P_{DF}}{k}, \quad (9)$$

where: P_{Bmax} – is the maximum possible price of biodiesel fuel, in UAH/l; P_{DF} – is the market retail price of diesel fuel, which, according to [12], is P_{DF} = 52,9 UAH/l; k = 1,07 – is the energy coefficient comparing the heat of combustion of diesel fuel and biofuel from rapeseed oil [4].

Substituting the values into formula (9), we obtain:

$$P_{Bmax} = \frac{P_{DF}}{k} = \frac{52{,}9}{1{,}07} = 49{,}44 \text{ UAH/l}.$$

Further, according to the mentioned methodology, we determine the margin from the potential sale of biofuel produced from our own raw materials:

- in absolute terms

$$\mathrm{M}_B = P_{Bmax} - \mathrm{C}_3, \quad (10)$$

$$\mathrm{M}_B = P_{Bmax} - \mathrm{C}_3 = 49{,}44 - 10{,}35 = 39{,}09 \text{ UAH/l};$$

- in relative terms

$$\mathrm{M}_B = \frac{P_{Bmax} - \mathrm{C}_3}{P_{Bmax}} \cdot 100, \quad (11)$$

$$\mathrm{M}_B = \frac{P_{Bmax} - \mathrm{C}_3}{P_{Bmax}} \cdot 100 = \frac{49{,}44 - 10{,}35}{49{,}44} \cdot 100 = 79{,}1 \text{ \%}.$$

Maximum profit from 1 ton of rapeseed:

$$Profit_{max} = \frac{\mathrm{M}_B \cdot m_B}{\rho_B}, \quad (12)$$

$$Profit_{max} = \frac{\mathrm{M}_B \cdot m_B}{\rho_B} = \frac{39{,}09 \cdot 450}{880 \cdot 10^{-3}} = 19989{,}2 \text{ UAH}.$$

Let us analyse the current market value of rapeseed, which according to [13], is P_{rap} = 21543 UAH/t.

We calculate the profit from selling rapeseed at the market price:

$$Profit_{rap} = P_{rap} - \mathrm{C}_{rm}, \quad (13)$$

$$Profit_{rap} = P_{rap} - \mathrm{C}_{rm} = 21543 - 6970 = 14573 \text{ UAH}.$$

We determine the profitability of rapeseed cultivation under the market price condition $P_{rap} =$ 21543 UAH/t:

$$Profitab_{rap} = \frac{Profit_{rap}}{C_{rm}} \cdot 100, \quad (14)$$

$$Profitab_{rap} = \frac{Profit_{rap}}{C_{rm}} \cdot 100 = \frac{14573}{6970} \cdot 100 = 209{,}1\ \%.$$

Next, let us determine the profitability of a two-stage processing of 1 ton of raw material into biofuel, assuming the maximum possible profit from selling biofuel at a margin of M=79,1%:

$$Profitab_B = \frac{Profit_{max} \cdot \rho_B}{C_3 \cdot m_B} \cdot 100, \quad (15)$$

$$Profitab_B = \frac{P_{rmax} \cdot \rho_B}{C_3 \cdot m_B} \cdot 100 = \frac{19989{,}2 \cdot 880 \cdot 10^{-3}}{10{,}35 \cdot 450} \cdot 100 = 377{,}7\ \%.$$

By equating formulas (14) and (15), we obtain the inequality:

$$\frac{Profit_{rap}}{C_{rm}} \cdot 100 < \frac{Profit_{max} \cdot \rho_B}{C_3 \cdot m_B} \cdot 100, \quad (16)$$

where the left side of the equation represents the profitability of rapeseed cultivation, $Profitab_{rap}$ = 209,1%, and the right side represents the profitability of two-stage processing of raw material into biofuel under its maximum market price condition, $Profitab_B$ = 377,7%.

Thus, equation (16) shows that with $Profitab_{rap}$ = 209,1% and $Profitab_B$ = 377,7% (under the condition of selling the produced biofuel at the maximum price), a business model with two-stage processing of rapeseed is preferable.

This raises the question: what business model should be used if the produced biofuel is sold at a non-maximum price? Or, at what price of biofuel would it be more profitable to sell the grown rapeseed instead of processing it into biofuel?

We determine the minimum feasible price of biofuel that corresponds to the profit from selling the raw material used for its production. For this, we use the general principles of forming the actual price P_B, based on the goal of generating profit and covering costs:

$$P_B = C_3 + Profit, \quad (17)$$

where $Profit$ – is the actual profit from selling biofuel produced from own raw material, UAH/liter.

Thus, the actual profit is:

$$Profit = P_B - C_3. \quad (18)$$

On the other hand, the profit from selling rapeseed is $Profit_{rap}$ = 14,573 UAH/ton. Considering the tasks outlined above, it is necessary to equate the two profits with different units of measurement.

For this, we propose the equation:

$$Profit_{rap} = Profit \frac{m_B}{\rho_B}, \quad (19)$$

Substituting formula (18) into expression (19):

$$Profit_{rap} = (P_B - C_3) \frac{m_B}{\rho_B}, \quad (20)$$

From formula (20), we express the biofuel price:

$$P_B = \frac{Profit_{rap} \cdot \rho_B}{m_B} + C_3. \quad (21)$$

By substituting the values into formula (21), we find the price of biofuel corresponding to the profit from selling the raw material used for its production:

$$P_B = \frac{Profit_{rap} \cdot \rho_B}{m_B} + C_3 = \frac{14573 \cdot 880 \cdot 10^{-3}}{450} + 10{,}35 = 38{,}85\ \text{UAH/l}.$$

Thus, we obtain the optimal margin, which is the difference between the maximum market price of biofuel and the minimum feasible price for sale:

$$M_{opt} = P_{Bmax} - P_B, \quad (22)$$

$$M_{opt} = 49{,}44 - 38{,}85 = 10{,}59\ \text{UAH/l},$$

or in relative terms:

$$M_{opt} = \frac{P_{Bmax} - P_B}{P_B} \cdot 100; \quad (23)$$

$$M_{opt} = \frac{49{,}44 - 38{,}85}{49{,}44} \cdot 100 = 21{,}4\ \%.$$

Thus, we answer the previously posed question. The margin for selling fuel made from its own raw materials amounts to 10,59 UAH/l or 21,4%**,** and the price should range between 38,85 and 49,44 UAH/l.

Based on this, we can conclude that biodiesel fuel produced on a farm using its own raw materials can compete with petroleum products in current market conditions.

If the market price of the produced biofuel is within the range of 38,85 to 49,44 UAH/l, it is advisable to use the business model of the two-stage processing of rapeseed. However, if the selling price of biofuel is 38,85 UAH/l or lower, it is more reasonable to adopt a business model focusing on cultivating rapeseed and selling it at market prices.

Let us consider another business model: the single-stage processing of rapeseed into edible oil.

We calculate the cost of single-stage processing of rapeseed from own raw materials C_{rml}. For this, we rewrite the cost formula (2) using the methodology presented in [4]:

$$C_{rml} = \frac{C_{rm} \cdot \rho_{RO}}{m_{RO} \cdot k_{pc}}, \quad (24)$$

where ρ_{RO} – density of rapeseed oil, ρ_{RO} = 919 kg/m^3 = 919·10^{-3} kg/l [14]; m_{RO} – oil yield from 1 ton of raw material during single-stage processing, m_{RO} = 450kg/t [3]; k_{pc} – production cost coefficient for oil manufacturing, characterizing the ratio of raw material costs to total costs for oil production, calculated based on data from the scientific work [3], k_{pc} = 0,9.

Substituting the data into formula (24), we obtain:

$$C_{rml} = \frac{C_{rm} \cdot \rho_{RO}}{m_{RO} \cdot k_{pc}} = \frac{6970 \cdot 919 \cdot 10^{-3}}{450 \cdot 0{,}9} = 15{,}82 \text{ UAH/l}.$$

Next, to calculate the cost of single-stage processing of oilseeds, considering the sale of by-products C_{l1}, we use formula (4), slightly modified:

$$C_{l1} = C_{rml} - V_{Arp1}, \quad (25)$$

$$C_{l1} = C_{rml} - V_{Arp1} = 15{,}82 - 10{,}76 = 5{,}06 \text{ UAH/l}.$$

Considering the wholesale price of marketable rapeseed oil, which, according to [15], is P_{RO} = 900 $/t, or in national currency (based on the NBU exchange rate for today) P_{RO} = 39420 UAH/t, we determine the maximum price per liter of marketable oil:

$$P_{ROmax} = \frac{P_{RO}}{\rho_{RO}} \quad (26)$$

$$P_{ROmax} = \frac{P_{RO}}{\rho_{RO}} = \frac{39420}{919} = 42{,}89 \text{ UAH/l}.$$

We calculate the margin from the potential sale of marketable oil made from our own raw materials using formula (10):

- in absolute terms:

$$M_{RO} = P_{ROmax} - C_{l1}, \quad (27)$$

$$M_{RO} = P_{ROmax} - C_{l1} = 42{,}89 - 5{,}06 = 37{,}83 \text{ UAH/l};$$

- in relative terms (based on formula (11)):

$$M_{RO} = \frac{P_{ROmax} - C_{l1}}{P_{ROmax}} \cdot 100 \quad (28)$$

$$M_{RO} = \frac{P_{ROmax} - C_{l1}}{P_{ROmax}} \cdot 100 = \frac{42{,}89 - 5{,}06}{42{,}89} \cdot 100 = 88{,}2\ \%.$$

The maximum profit from single-stage processing of 1 ton of rapeseed into marketable oil, based on formula (12):

$$Profit_{lmax} = \frac{M_{RO} \cdot m_{RO}}{\rho_{RO}}, \quad (29)$$

$$Profit_{lmax} = \frac{M_{RO} \cdot m_{RO}}{\rho_{RO}} = \frac{37{,}83 \cdot 450}{919 \cdot 10^{-3}} = 18523{,}94 \text{ UAH}.$$

Let us determine the profitability of producing marketable oil from our own raw materials under the condition of maximum profit from its sale with a margin M_{RO} = 88,2%, based on formula (15):

$$Profitab_{RO} = \frac{Profit_{lmax} \cdot \rho_{RO}}{C_{l1} \cdot m_{RO}} \cdot 100, \quad (30)$$

$$Profitab_{RO} = \frac{Profit_{lmax} \cdot \rho_{RO}}{C_{l1} \cdot m_{RO}} \cdot 100 = \frac{18523{,}94 \cdot 919 \cdot 10^{-3}}{5{,}06 \cdot 450} \cdot 100 = 747{,}63\ \%.$$

We now reframe the question, but this time – which of the three business models should be used: two-stage processing of oilseeds into biofuel, single-stage processing of oilseeds into marketable oil, cultivation, and sale of oilseeds?

To solve this problem, we construct the following inequality:

$$Profit_{max} > Profit_{\text{l}max} > Profit_{rap}. \quad (31)$$

To confirm the inequality, we substitute the values:

$$19989{,}2 > 18523{,}94 > 14573.$$

As seen from the inequality, from the perspective of economic feasibility, the priority is as follows: the business model of two-stage processing of rapeseed into biodiesel comes first, the single-stage processing of rapeseed into edible oil ranks second, the model of cultivating and selling rapeseed is third.

Given these priorities, let us calculate the minimum feasible selling price of biofuel, taking into account a comparison of the two processing business models: two-stage processing into biofuel and single-stage processing into marketable oil.

Based on the formulated task, we rewrite inequality (31) without the third term:

$$Profit_{max} > Profit_{\text{l}max}. \quad (32)$$

We transform inequality (32) into an equation using formulas (20) and (29):

$$Profit_{\text{l}max} = \frac{(P_B - \text{C}_3)\cdot m_B}{\rho_B}, \quad (33)$$

We express the biofuel price from equation (33):

$$P_B = \frac{Profit_{\text{l}max}\cdot \rho_B}{m_B} + \text{C}_3, \quad (34)$$

Substituting the values into equation (34), we find:

$$P_B = \frac{Profit_{\text{l}max}\cdot \rho_B}{m_B} + \text{C}_3 = \frac{18523{,}94 \cdot 880 \cdot 10^{-3}}{450} + 10{,}59 = 46{,}81 \text{ UAH/l}.$$

Thus, we obtain the optimal margin, which is the difference between the maximum market price of biofuel obtained through two-stage processing of rapeseed and the minimum feasible price for its sale, which equals the maximum selling price of oil obtained through single-stage processing of rapeseed, using formulas (22) and (23):

$$\text{M}_{opt} = P_{Bmax} - P_B = 49{,}44 - 46{,}81 = 2{,}63 \text{ UAH/l},$$

or in relative terms:

$$\text{M}_{opt} = \frac{P_{Bmax} - P_B}{P_{Bmax}} \cdot 100 = \frac{49{,}44 - 46{,}81}{49{,}44} \cdot 100 = 5{,}3\ \%.$$

Thus, the solution to the next task of comparing two-stage and single-stage processing of rapeseed into biofuel and marketable oil is as follows. The margin for selling fuel made from our own raw materials is 2,63 UAH/l or 5,3%**,** and the price should range from 46,81 to 49,44 UAH/l.

If the market price of the produced biofuel is within the range of 46,81 to 49,44 UAH/l, it is advisable to use the business model of the two-stage processing of rapeseed into biofuel**.** If the selling price of biofuel is 46,81 UAH/l or lower, it is more reasonable to adopt the business model of single-stage processing of rapeseed into marketable oil.

However, to compare all three business models of utilizing alternative fuels, it remains to compare two more models: the single-stage processing of rapeseed into marketable oil and the model of cultivating rapeseed and selling it at market prices.

To do this, we write inequality (31) without the first term:

$$Profit_{\text{l}max} > Profit_{rap}. \quad (35)$$

We transform inequality (35) into an equation based on equation (19), using formulas (27) and (29):

$$Profit_{rap} = \frac{(P_{RO} - \text{C}_{\text{l}1})\cdot m_{RO}}{\rho_{RO}}, \quad (36)$$

where P_{RO} – is the actual price of rapeseed oil.

We express the price of rapeseed oil from equation (36):

$$P_{RO} = \frac{Profit_{rap}\cdot \rho_{RO}}{m_{RO}} + \text{C}_{\text{l}1}, \quad (37)$$

$$P_{RO} = \frac{Profit_{rap}\cdot \rho_{RO}}{m_{RO}} + \text{C}_{\text{l}1} = \frac{14573 \cdot 919 \cdot 10^{-3}}{450} + 5{,}06 = 34{,}82 \text{ UAH/l}.$$

The optimal margin, which represents the difference between the minimum feasible price for biodiesel production P_B (and therefore the maximum price at which it becomes feasible to produce commercial oil instead of biofuel) and the maximum price for rapeseed realization P_{RO}, is calculated using formulas (22) and (23):

$$\text{M}_{optRO} = P_{ROmax} - P_{RO} \quad (38)$$

$$\text{M}_{optRO} = P_{ROmax} - P_{RO} = 42{,}89 - 34{,}82 = 8{,}07 \text{ UAH/l},$$

or in relative terms:

$$M_{optRO} = \frac{P_{ROmax} - P_{RO}}{P_{ROmax}} \cdot 100 \quad (39)$$

$$M_{optRO} = \frac{P_{ROmax} - P_{RO}}{P_{ROmax}} \cdot 100 = \frac{42{,}89 - 34{,}82}{42{,}89} \cdot 100 = 18{,}8\ \%.$$

Thus, the results of comparing the business models for single-stage processing of rapeseed into commercial oil and growing rapeseed for sale at market prices are as follows. The margin for selling oil produced from own raw materials, provided that biodiesel production becomes unfeasible, is 8,07 UAH/l or 18,8%, and the price should range from 34,82 to 42,89 UAH/l.

In this case, if the market price of the produced rapeseed oil is between 34,82 and 42,89 UAH/l, it is advisable to apply the business model of single-stage processing of rapeseed. However, if the selling price of biofuel is 34,82 UAH/l or lower, it is advisable to use the business model of growing and selling rapeseed at market prices.

Finally, let's calculate the margin for selling rapeseed, modifying formulas (22) and (23) accordingly:

$$M_{rap} = P_{rap} - C_{rm}, \quad (40)$$

$$M_{rap} = P_{rap} - C_{rm} = 21543 - 6970 = 14573\ \text{UAH}/t,$$

or in relative terms:

$$M_{rap} = \frac{P_{rap} - C_{rm}}{P_{rap}} \cdot 100 \quad (41)$$

$$M_{rap} = \frac{P_{rap} - C_{rm}}{P_{rap}} \cdot 100 = \frac{21543 - 6970}{21543} \cdot 100 = 67{,}6\ \%.$$

3. The purpose of the article

The aim of the article is to substantiate the feasibility of manufacturing and the efficiency of using biodiesel fuel produced from self-sourced raw materials by an agricultural producer.

4. Results of the researches

Analysis and Strategy for Maximizing Profit from Rapeseed Cultivation and Processing. Based on the research findings, we can formulate a strategy for a farm specializing in rapeseed cultivation to maximize profit using three business models:

- growing rapeseed and selling its seeds at market prices;
- single-stage processing of rapeseed seeds into edible oil and selling it at market prices;
- two-stage processing of rapeseed seeds into biodiesel fuel and selling it at market prices.

Conditions for Business Models.

Two-stage processing: feasible when the market price for biodiesel exceeds 46,81 UAH/l, making it competitive with petroleum products. At the maximum biodiesel price P_{Bmax} = 49,44 UAH/l, the maximum possible profit is $Profit_{max}$ = 19989,2 UAH/t, with a profitability $Profitab_B$ = 377,7%, margin $M_{opt} = 2{,}63$ UAH/l, or 5.3%, and cost price $C_3 = 10{,}35$ UAH/l.

Single-stage processing: feasible when the market price of biodiesel is 46,81 UAH/l or lower, and the price of rapeseed oil exceeds 34,82 UAH/l. At the maximum wholesale price for rapeseed oil P_{ROmax} = 42,89 UAH/l, the maximum profit is $Profit_{lmax}$ = 18523,94 UAH/t, with a profitability $Profitab_{RO}$ = 747,63%, M_{optRO} = 8,07UAH/l or 18,8%, and cost price $C_{l1} = 5{,}06$ UAH/l.

Rapeseed cultivation: feasible when the market price of biodiesel is 46,81 UAH/l or lower, and the price of rapeseed oil is 34,82 UAH/l or lower. At the maximum wholesale price for rapeseed seeds P_{rap} = 21543 UAH/t, the maximum profit is $Profit_{rap}$ = 14,573 UAH/t, with a profitability $Profitab_{rap}$ = 209,1% or 67,6%, and cost price C_{rm} = 6970 UAH/t.

Calculation of Profitability-Dependence Functions**.** To visualize the analytical data, we construct graphical dependencies of profitability on profit for the three business models:

- for rapeseed cultivation profitability function $Profitab_{rap} = f(Profit_{rap})$;
- for single-stage processing derived profitability function $Profitab_{RO} = f(Profit_{l})$;
- for the two-stage processing business model of rapeseed into biodiesel fuel $Profitab_B = f(Profit)$.

To calculate the function arguments, we use the following formulas:

- for the rapeseed cultivation model – formula (13).

- for the single-stage processing model – based on formulas (27) and (29), we derive the dependence:

$$Profit_{\text{I}} = \frac{(P_{RO} - \text{C}_{\text{I}1}) \cdot m_{RO}}{\rho_{RO}}; \quad (42)$$

- for the two-stage processing model – based on formulas (10) and (12), we derive:

$$Profit = \frac{(P_B - \text{C}_3) \cdot m_B}{\rho_B}. \quad (43)$$

Constants for Formulas (13), (40), and (41):

- cost indicators C_{rm} = 6970 UAH/t, $\text{C}_{\text{I}1}$ = 5.06 UAH/l, $\text{C}_3 = 10{,}35$ UAH/l correspond to the cultivation of rapeseed, production of rapeseed oil, and biodiesel production, respectively, per ton of rapeseed.

- output per ton of raw material (rapeseed) m_{RO} = 450 kg/t, m_B = 450 kg/t for rapeseed oil and biodiesel fuel, respectively.

- densities $\rho_{RO} = 919 \cdot 10^{-3}$ kg/l, $\rho_B = 880 \cdot 10^{-3}$ kg/l for rapeseed oil and biodiesel fuel, respectively.

The variable parameters in formulas (13), (40), and (41) are prices: P_{rap}, P_{RO} та P_B – respectively, rapeseed price in UAH/t, rapeseed oil and biodiesel price in UAH/l.

To model using formulas (13), (40), and (41), we use the Microsoft Excel spreadsheet environment, where we input constant coefficients and variable parameters.

The rapeseed price will be varied from the minimum value equal to its production cost $P_{rap} = \text{C}_{rm}$ 6970 UAH/t to the maximum value $P_{rap} = P_{rapmax}$ = 21543 UAH/t, with a step of 100 UAH/t.

The rapeseed oil price is also changed from the minimum value equal to its production cost $P_{RO} = \text{C}_{\text{I}1}$ = 5,06 UAH/l to the maximum value $P_{RO} = P_{ROmax}$ = 42,89 UAH/l, with a step of 0,25 UAH/l.

The biodiesel price is changed similarly from $P_B = \text{C}_3$ = 10,35 UAH/l to the maximum value $P_B = P_{Bmax}$ = 49,44 UAH/l, with a step of 0,25 UAH/l.

The function values $Profitab_{rap} = f(Profit_{rap})$ are calculated using formula (14), and $Profitab_{RO} = f(Profit_{\text{I}})$, $Profitab_B = f(Profit)$ using formulas (30) and (15), respectively, replacing the maximum profit values $Profit_{\text{I}max}$ and $Profit_{max}$ with actual $Profit_{\text{I}}$ and $Profit$:

$$Profitab_{RO} = \frac{Profit_{\text{I}} \cdot \rho_{RO}}{\text{C}_{\text{I}1} \cdot m_{RO}} \cdot 100, \quad (44)$$

$$\text{P}_B = \frac{Profit \cdot \rho_B}{\text{C}_3 \cdot m_B} \cdot 100. \quad (45)$$

Formulas (12–13), and (42–45) are recorded in the corresponding spreadsheet cells, and profit and profitability values are calculated for three different business models as the price of the produced product changes. A fragment of the Microsoft Excel table is presented in Table 1.

Table 1

Fragment of the calculation of economic indicators for the sale of rapeseed and its processed products in Microsoft Excel spreadsheets

Profit			**Profitability**			**Margin**			**Price**			**Cost**		**Yield, kg/t**	**Density, kg/t**	
Rap, UAH/t	**RO, UAH/t**	**B, UAH/t**	**Rap, %**	**RO, %**	**B, %**	**Rap, %**	**RO, %**	**B, %**	**Rap, UAH/t**	**RO, UAH/l**	**B, UAH/l**					
0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	6970	5,06	10,35	6970	**Rap, UAH/t**			
30	93	77	0,4	3,8	1,4	0,4	3,6	1,4	7000	5,25	10,50	5,06	**RO, UAH/l**	450	0,919	**Oils**
130	215	205	1,9	8,7	3,9	1,8	8,0	3,7	7100	5,50	10,75	10,35	**B, UAH/l**	450	0,880	**B**
230	338	332	3,3	13,6	6,3	3,2	12,0	5,9	7200	5,75	11,00					
330	460	460	4,7	18,6	8,7	4,5	15,7	8,0	7300	6,00	11,25					

Constant parameters are entered into yellow-highlighted cells, and variable indicators into white-highlighted cells.

Based on the resulting tabular data, graphical dependencies of profitability on profit are built for the three proposed business models (Fig. 1).

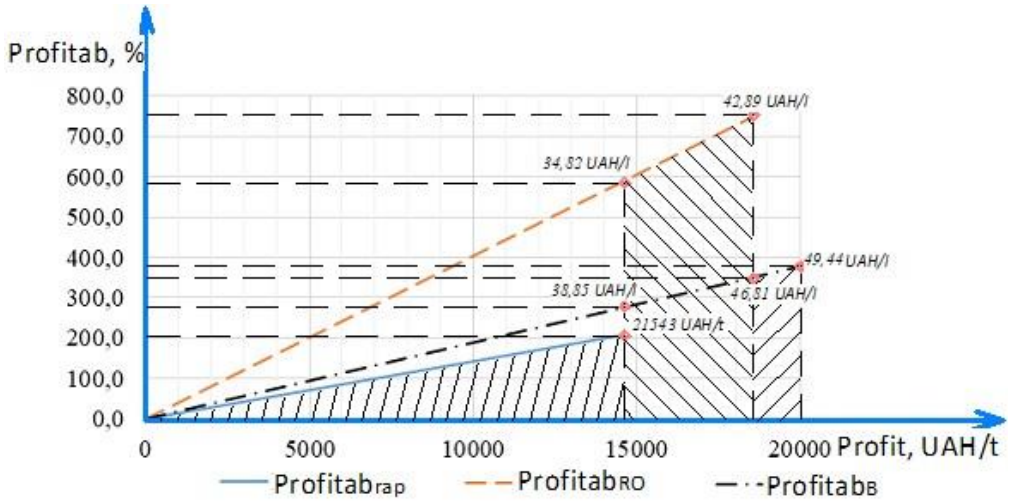

Fig. 1 – Dependency of profitability on profit when using three different business models for rapeseed seed implementation:

Profitab$_{rap}$ ***– cultivation of rapeseed seeds and their sale at market prices;***

Profitab$_{RO}$ ***– single-stage processing of rapeseed seeds into commercial edible oil;***

Profitab$_{B}$ ***– two-stage processing of rapeseed seeds into biodiesel fuel.***

As can be seen from the graphs, the profitability functions depending on profit have a clearly linear character.

The line for the rapeseed growing business model $Profitab_{rap} = f(Profit_{rap})$ is a solid blue line with the smallest angle to the abscissa axis.

The line for the single-stage processing of rapeseed into marketable oil $Profitab_{RO} = f(Profit_{\text{I}})$ is an orange dashed line with the maximum angle to the abscissa axis.

The line for the two-stage processing of rapeseed into biodiesel $Profitab_{B} = f(Profit)$ is a black dash-dot line with an average angle to the abscissa axis.

The slope of the lines depends on the profitability of the model in such a way that the higher the profitability, the steeper the slope.

The points of maximum profit are marked at the right ends of the respective lines and clearly depend on the selling price of the corresponding products. As we can see, the highest profit is achievable using the two-stage rapeseed processing business model for biofuel production at a price of $P_B = P_{Bmax}$ = 49,44 UAH/l (the rightmost point on the dashed-dotted line). The second most profitable model is the single-stage processing of rapeseed into commercial oil, as indicated by the rightmost point on the dotted line at $P_{RO} = P_{ROmax}$ = 42,89 UAH/l. The lowest profitability is achieved with the solid line, which represents the business model of growing rapeseed and selling its seeds at market prices, at $P_{rap} = P_{rapmax} = 21543$ UAH/t.

The leftmost points of the profitability and profit lines for all three models coincide at the graph's origin, i.e., they are equal to zero.

Analysis of Characteristic Points. We examine other characteristic points of the profitability lines family. From each characteristic point, perpendiculars are dropped to the axes of profit and profitability (thin dashed lines). These lines help determine the coordinates of the characteristic points, and the digital labels of these points correspond to the price of the respective product, which determines both profit and profitability.

Assessment of the conditions for applying models. To determine the feasibility of using a particular business model, consider the areas bounded by lines dropped from the right ends of the lines and shade the respective planes.

Trapezoid 1: Positioned between the end of the line $Profitab_{B} = f(Profit)$, which corresponds to the maximum profit and profitability of the two-stage processing of rapeseed into biofuel, and the end of the line $Profitab_{RO} = f(Profit_{\text{I}})$, which corresponds to the maximum profit and profitability of single-stage processing of rapeseed into commercial oil. The lateral sides of the trapezoid correspond to the coordinates $Profit$ = 19989 UAH/t and $Profit$ = 18524 UAH/t, respectively, indicating the maximum and minimally feasible profits for the two-stage processing model. The base of the trapezoid corresponds to the difference between these profits: $\Delta\, Profit$ = 19989 – 18524 = 1465 UAH/t. The upper side of the trapezoid is a segment

of the line $Profitab_B = f(Profit)$, corresponding to profitability coordinates: maximum $Profitab_B$ = 377,7% at a biofuel price of P_B = 49,44 UAH/l, and approximately $Profitab_B \approx$ 351–354% at a price of P_B = 46,81 UAH/l. This side effectively characterizes the margin ΔP_B = 49,44 – 46,81 = 2,63 UAH/l for the two-stage model. The shaded trapezoid characterizes the zone of feasibility for using this model.

Trapezoid 2: Positioned between the end of the line $Profitab_{RO} = f(Profit_{\text{l}})$, which corresponds to the maximum profit and profitability of single-stage processing, and the end of the line $Profitab_{rap} = f(Profit_{rap})$, which corresponds to the maximum profit and profitability of growing rapeseed and selling it at market prices. The lateral sides of this trapezoid correspond to the coordinates $Profit$ = 18524 UAH/t and $Profit$ = 14573 UAH/t, respectively. The base corresponds to the difference: ΔP_{RO} = 18524 – 14573 = 3951 UAH/t. The upper side of the trapezoid reflects the profitability: maximum $Profitab_{RO}$ = 747,6% at an oil price of P_{RO} = 42,89 UAH/l and approximately $Profitab_{RO} \approx$ 586–592% at a price of P_{RO} = 34,82 UAH/l. This side characterizes the margin ΔP_{RO} = 42,89 – 34,82 = 8,07 UAH/l for the single-stage model.

Isosceles Triangle: The hypotenuse of which is the line $Profitab_{rap} = f(Profit_{rap})$. One leg passes through the graph's endpoint $Profitab_{rap} = f(Profit_{rap})$ (thin dashed line), perpendicular to the x-axis, corresponding to the maximum profit of $Profit$ = 14573 UAH/t. The other leg reflects the difference between the maximum and minimum profit, which equals 0. The hypotenuse reflects the difference in profitability, which at a price of $P_{rap} = P_{rapmax} = 21543$ UAH/t is $Profitab_{rap}$ = 209,1%, and at $Profitab_{rap}$ = 6,970 UAH/t equals 0. And the shaded area of the triangle represents the feasibility and economic efficiency of this model.

In the graphs (see Fig. 1), we observe a somewhat paradoxical situation: the profitability line based on profit for the single-stage processing business model (dotted line) is slightly steeper than the corresponding line for the two-stage processing model (dashed-dotted line). This indicates greater profitability for single-stage processing, although logically it should be the opposite since two-stage processing produces by-products at each stage, increasing added value and reducing production costs.

This paradox is explained by the fact that after processing rapeseed oil into biofuel, the resulting product becomes an excise-taxable commodity, which requires the enterprise to bear additional costs by paying excise tax. This, in turn, increases the production cost (10,35 UAH/l for biofuel compared to 5,06 UAH/l for commercial oil).

Modelling a Strategy for a Rapeseed Farming Enterprise. After the harvest, the farm manager or another responsible person should analyze pricing policies in the grain market, the oil and fat products market, and the fuel market.

Since rapeseed farming is seasonal, we assume that the harvested products or their processed derivatives should be sold before the next harvest, meaning the planning horizon is one year.

Based on these considerations, an annual plan for the two-stage processing of rapeseed oil into biofuel is developed and followed under favorable fuel price conditions. If prices are unfavorable or there is insufficient demand for biodiesel fuel and other factors prevent product realization as planned, the model should shift to single-stage processing of rapeseed into commercial oil. If prices for both oil and fuel are unfavorable or demand is insufficient, the model shifts to rapeseed farming and selling the seeds at market prices.

However, it should be noted that in some cases, when there is a need for rapid profit generation (to secure working capital, settle payments with unit holders, etc.), multiple implementation models can be used simultaneously.

Profitability Analysis. Based on the graphical characteristics of profitability and profit, we see that at a profit of $Profit$ = 14573 UAH/t, corresponding to the following product prices: $P_{rap} = 21543$ UAH/t, P_B = 38,85 UAH/l and P_{RO} = 34,82 UAH/l, the respective profitability figures for the business models are: cultivation – $Profitab_{rap}$ = 209,1%, two-stage processing – $Profitab_B \approx$ 275%, single-stage processing – $Profitab_{RO} \approx$ 586–592%.

Practical Applications. In this case, the priority should be the cultivation model, which involves minimal costs for equivalent profit levels. However, if production volumes are so large that logistical, organizational, and other factors delay the sale of rapeseed at a competitive price, the single-stage processing model can be used simultaneously, generating two streams of profit. If even the combination of single-stage processing and cultivation does not allow for high realization rates, the two-stage processing model can be added to create another source of profit.

Advantages of Using Three Business Models. Employing all three rapeseed implementation models provides significant advantages:

- accelerated working capital turnover for further business activities;

- maximizing profits depending on market prices for rapeseed, rapeseed oil, and diesel fuel;
- adjusting and regulating product realization rates based on the logistical capabilities of the enterprise.

Margin Analysis. For margin analysis, similar calculations are performed using Microsoft Excel spreadsheets to build graphical dependencies of margins on profits for all three business models.

To build these dependencies, the following functions are used:

- for the rapeseed cultivation and seed selling model: $Profitab_{rap} = f(Profit_{rap})$;
- for the single-stage processing model into commercial edible oil: $Profitab_{RO} = f(Profit_1)$;
- for the two-stage processing model into biodiesel fuel: $Profitab_B = f(Profit)$.

To calculate the function arguments, we use the same formulas as for the previous characteristics (13), (42), and (43), and compute them in a similar manner (see Table 1).

The value of the function $M_{rap} = f(Profit_{rap})$ is calculated using formula (41), while $M_{RO} = f(Profit_{RO})$ and $M_B = f(Profit_B)$ are calculated using formulas (39) and (11), with slight modifications:

$$M_{RO} = \frac{P_{RO} - C_{I1}}{P_{RO}} \cdot 100, \quad (46)$$

$$M_B = \frac{P_B - C_3}{P_B} \cdot 100. \quad (47)$$

The formulas (12–13), (41–43), and (46–47) are entered into the appropriate cells of the spreadsheet, and the profit and margin values for the three different business models are calculated based on changes in the price of the produced goods. A fragment of the Microsoft Excel table is shown in Table 1.

Based on the tabular data, graphical dependencies of margins on profits for the proposed three business models are constructed (see Fig. 2).

As we can see from the graphs, the margin functions based on profit are not linear and can be described either by a hyperbolic function, a logarithmic function, or a third-degree polynomial. The graph (see Fig. 2) is similarly divided into shaded zones representing the feasibility of using a particular business model (as shown in Fig. 1) and is analyzed in a similar manner.

The margin indicator serves as a key metric for planning marketing activities. As we can see from the graph (see Fig. 2), the maximum product margin is achieved in the single-stage processing model, $M_{RO} = 88{,}2$ %. The second highest margin is in the two-stage processing model, at $M_B = 79{,}1$ %, while the cultivation model ranks third with a margin of $M_{rap} = 67{,}6$ %.

A marketer should take this into account when developing strategies for product realization.

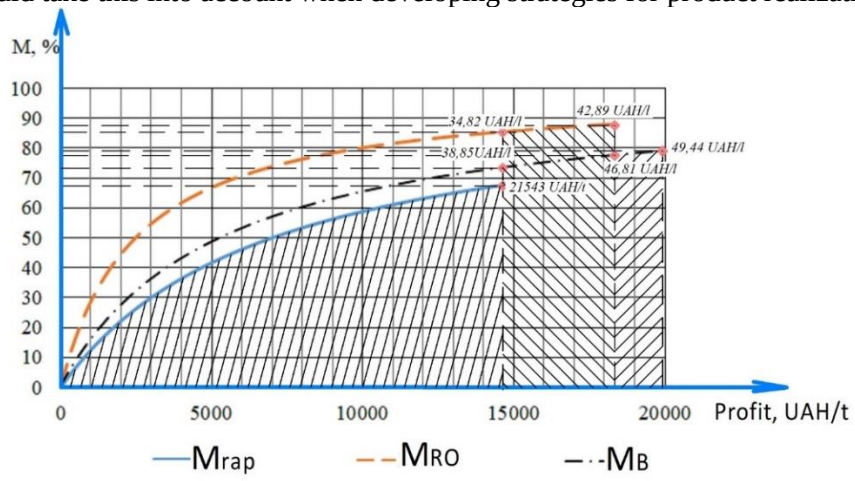

Fig. 2 – Dependency of margin on profit when using three different business models for rapeseed seed implementation:

—Mrap – ***cultivation of rapeseed seeds and their sale at market prices;***

– –MRO– ***single-stage processing of rapeseed seeds into commercial edible oil;***

– ·-MB – ***two-stage processing of rapeseed seeds into biodiesel fuel.***

5. Conclusions

1. A methodology has been developed to assess the feasibility of biodiesel production at a farm using its own raw materials. This methodology involves three conditional business models for product implementation, using rapeseed as an example:

- cultivation and sale of oilseeds at market prices;
- single-stage processing of oilseeds into commercial oil and its sale at wholesale market prices;
- two-stage processing of oilseeds into biodiesel and its sale at market prices for petroleum products.

2. The most profitable business model examined in this study is the two-stage processing of rapeseed into biofuel, with a maximum profit of $Profit_{max}$ = 19989,2 UAH/t, a biofuel price of P_B = 49,44 UAH/l, and a production cost, taking into account by-products at each production stage, of C_3 = 10.35 UAH/l. This indicates that biofuel produced from own raw materials can compete in the market with standard petroleum fuel.

3. The most profitable model in terms of profitability is the single-stage processing of rapeseed into commercial oil, with profitability of $Profitab_{RO}$ = 747.6%, a wholesale oil price of P_{RO} = 42,89 UAH/l, and a production cost of C_{l1} = 5,06 UAH/l.

4. Based on the calculations, graphical dependencies of profitability and margin on profit were constructed for all three business models. These graphs highlight the zones of feasibility for each business model from the perspective of maximizing profit. For example: in the price range for biodiesel from 46,81 to 49,44 UAH/l, the two-stage rapeseed processing model is recommended; in the price range for rapeseed oil from 34,82 to 42,89 UAH/l, the single-stage processing model is preferable; when the oil price drops to 34,82 UAH/l or below, the model of cultivating and selling rapeseed at market prices should be adopted.

5. Based on the data analysis and graphical dependencies, a product implementation strategy was proposed. This strategy involves selecting one of the three models, taking into account their priorities, to achieve the highest possible profit. Additionally, the conditions under which the priority of models can be violated and two or three models used simultaneously were considered.

6. A paradox was formulated in this study: the profitability of single-stage rapeseed processing is higher than that of two-stage processing. This is even though two-stage processing generates added value through the sale of by-products at each stage. The reason lies in the lower production cost of the single-stage model (C_{l1} = 5,06 UAH/l) compared to the two-stage model (C_3 = 10,35 UAH/l) due to the inclusion of excise tax in the production cost of biodiesel.

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КОМПЛЕКСНЕ ДОСЛІДЖЕННЯ КРИТЕРІЇВ ДОЦІЛЬНОСТІ ВИРОБНИЦТВА БІОДИЗЕЛЬНОГО ПАЛИВА НА БАЗІ ФЕРМЕРСЬКИХ ГОСПОДАРСТВ

Наведена актуальність виробництва біодизельного палива на базі фермерських господарств. Розроблена оцінка собівартості виробництва біодизельного палива, за якою обґрунтовано доцільність його виготовлення за умови використання власної сировини, отриманої з насіння олійних культур, вирощених в результаті фермерської господарської діяльності. Запропоновано, для оцінки ефективності та доцільності виробництва олійного насіння та продукції, що з нього виготовляється, розглядати три бізнес-моделі реалізації: вирощування ріпаку та продажу його насіння за ринковими цінами, одностадійної переробки ріпакового насіння в олію для харчових цілей та двостадійної переробки ріпакового насіння в біодизельне паливо. Прораховані такі економічні показники як собівартість, прибуток, рентабельність та маржу в залежності від обраної моделі, на основі яких обґрунтовано доцільність реалізації ріпаку одним із трьох шляхів. Запропоновано стратегію реалізації ріпаку чи продукції, виготовленої з нього, в тому числі й біодизельного палива, обираючи пріоритетну бізнес-модель виходячи з умов отримання максимального прибутку. Розглянуто також умови, при яких може бути застосована та чи інша бізнес модель не тільки з міркувань отримання максимального прибутку, а також умови паралельного використання двох або всіх трьох моделей реалізації насіння ріпаку. Побудовані графічні залежності рентабельності та маржинальності від прибутку для всіх трьох моделей, які поділені на зони доцільності застосування тої чи іншої бізнес-моделі в залежності від ринкових цін на відповідну продукцію. Доведено доцільність двостадійної переробки насіння ріпаку в біодизельне паливо, яке може конкурувати з нафтовим дизельним паливом на ринку рідких палив. В даній науковій праці представлені результати виконання ініціативної науково-дослідної роботи 0122U002187.

Для подальшого підвищення практичної застосовності запропонованих моделей було оцінено екологічні переваги виробництва біодизеля, підкресливши його роль у скороченні викидів парникових газів і сприянні сталим сільськогосподарським практикам. Крім того, було проаналізовано розвиток сільських територій, продемонструвавши, як виробництво біодизеля може сприяти створенню робочих місць, енергетичній незалежності та диверсифікації джерел доходу для сільськогосподарських підприємств.

Ключові слова: *біодизельне паливо, ріпакова олія, насіння ріпаку, двостадійна переробка, собівартість, одностадійна переробка, прибуток, рентабельність, маржа.*

Ф. 47. Рис. 2. Табл. 1. Літ. 15.

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