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CONCEPTUAL POLYCOMPONENT MODEL OF AN INNOVATIVE MECHANISM FOR IMPROVING THE COMPETITIVENESS OF AGRO-INDUSTRIAL COMPLEX ENTERPRISES

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Abstract. The modern agricultural sector is going through a period of intense transformation caused by both internal and external factors. In the context of active globalisation, business entities are forced to withstand fierce competition and therefore need to constantly adapt to the environment. This creates an urgent need for agribusiness enterprises to constantly improve their approaches and mechanisms of operation. Continuous adaptation requires flexibility, innovation and strategic thinking. Changes in the economic, political and technological landscape require businesses to respond quickly to new opportunities and challenges to ensure their competitiveness and sustainability. This constant process of adaptation is becoming a prerequisite not only for success, but also for survival in today's global business environment. The *purpose* of the article is to develop an innovative mechanism for improving the competitiveness of agribusiness enterprises. *Methodology*. The methodological basis of the study, which objectively reveals and substantiates the problem of increasing the competitiveness of agro-industrial enterprises using the model of the innovation mechanism, is based on such special and general scientific methods as: monographic, logical-theoretical, statistical and economic-mathematical, visualisation, system analysis, neural network modelling, logical generalisation, abstraction and conclusion formation. The information base of the study was formed by the materials of the State Statistics Service of Ukraine, statistical yearbooks, scientific developments of scientists on the defined topic, and financial statements of the studied enterprises. The subject and object basis of the study is the entrepreneurial activity of agricultural enterprises in Vinnytsia Oblast: Agricultural complex "Zelena Dolyna", PJSC "Dashkivtsi", LLC "Selyshchanske", FE "Yavir", FE "IRYNA – O.T". The *results* of the study have shown that the innovation mechanism, which consists in ensuring the management of innovative development of agribusiness enterprises, involves adjusting the business environment of an economic entity to achieve a cumulative effect from the efficient use of innovative and energy potentials. The paper emphasises that the cumulative effect means that the effect of the interaction of innovation and energy resources exceeds the simple effect of the impact of each of them separately. *Practical implications*. The authors calculated the indicators of competitiveness of the studied agricultural enterprises of Vinnytsia Oblast; assessed the level of innovation potential of these enterprises; determined the indicators of energy potential. On the basis of the obtained diagnostic results, a fuzzy knowledge base has been formed and a multicomponent decision-making system has been built for various combinations of values of the components of the innovation mechanism.

Keywords: agricultural complex, enterprise, competitiveness, innovation mechanism, sustainable development, biofuels, energy independence.

JEL Classification: O13, P28, Q12

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1. Introduction

Throughout Ukraine's history, the agro-industrial complex (AIC) has been one of the priority sectors of the national economy. The main areas of entrepreneurship in the agricultural sector of the economy are to ensure national food security and compliance with the global market conditions in view of the export-oriented production structure.

The classical concept of defining the essence and functional features of entrepreneurship is the desire to outperform competitors. The main criterion for the successful functioning of any enterprise is its ability to occupy a leading position among enterprises producing similar goods and services, as well as to attract the largest number of consumers. Therefore, the successful implementation of the main directions of the AIC development is possible only if business entities increase their competitive advantages, thereby increasing their competitiveness.

In the context of modern globalisation transformations, which are determined by fierce international competition among business entities, it is vital for enterprises to constantly adapt and maintain the efficiency of business processes. In view of the above, it is believed that innovation-oriented competition, in particular with elements of implementation of the system of production and consumption of renewable energy sources of agricultural origin, is a key form of business activity in the agricultural sector. Within this form of relations, innovations are the basis for ensuring the formation of competitive advantages and maintaining market positions.

Vinnytsia National Agrarian University is actively researching the issue of increasing the competitiveness of agricultural enterprises as part of its research work on the topic: "Development of mechanisms for increasing the competitiveness of enterprises of the AIC and ensuring energy independence of rural areas through the intensification of biofuel production" (state registration number 0124U000340).

2. Literature Review

The impact of the innovation mechanism on increasing the competitiveness of agricultural enterprises is the subject of research by leading scientists. In particular, Kaletnik G. and Lutkovska S., researching an innovative ecological strategy of sustainable development, claim that only the transition to higher standards of world experience can lead to progress in accelerating the increase of competitiveness of the national economy. Supporting the authors' opinion, it is believed that borrowing international experience is also appropriate at the micro-level in order to increase the competitiveness of agribusiness enterprises (Kaletnik, Lutkovska 2020). Economists Honcharuk I., Tokarchuk D., et al. have been quite successful in their scientific research in demonstrating the potential of Ukraine for the production of biogas/biomethane from organic waste of various origins (including agricultural) for climate neutrality and the development of a "green" economy. In addition, the scientists have developed recommendations for the production of biofuels for Ukrainian agribusinesses and provided examples of successful biofuel producers (Honcharuk, 2024a). Klius Y. and Syvochka V. propose the introduction of corporate innovation management to ensure the competitiveness of enterprises with the aim of creating corporate structures that combine the spheres of production and scientific and technical activity (Klius, Syvochka, 2023). Harbar Z., Selezneva O., et al. study the strategic marketing management of innovation activities in order to create and maintain the economic security of business entities (Harbar, 2020). Manikandan S., Subbaiya R., et al. prove in their scientific works that sustainability, regional development, reduction of greenhouse gas emissions, social infrastructure, agriculture are the priorities that will be ensured by the production of biofuels (Manikandan, 2022). Shweta J. Malode, K. Keerthi Prabhu, et al. examine in detail the processes of profitability of biofuel production, which is divided into 4 generations of biofuels depending on the raw material. In particular, the authors show the main technologies of biofuel production, their advantages and disadvantages, prospects of use (Shweta J. Malode, 2021). Scientists Honcharuk I., Tomashuk I. pay considerable attention to innovative approaches to the development of entrepreneurship and increasing its competitiveness in rural areas (Honcharuk, Tomashuk, 2023). Volyk S., Kukhar O., et al. identify increasing the level of competitiveness of agricultural formations as a priority direction for the development of the agricultural sphere of the national economy and propose a model of the mechanism of management of competitiveness of agricultural enterprises, which includes economic, organisational and legal subsystems (Volyk, 2023). Despite the significant number of publications on the subject, it is considered that further research is needed.

3. The State of Competitiveness of the Ukrainian Agro-industrial Complex

The agro-industrial complex of Ukraine is one of the few sectors of the Ukrainian economy that, despite the economic and political crisis and other negative factors, shows a fairly high level of stability in its functioning. For example, over the past 10 years, agriculture has generated an average of about 10% of gross domestic product (GDP) (Figure 1).

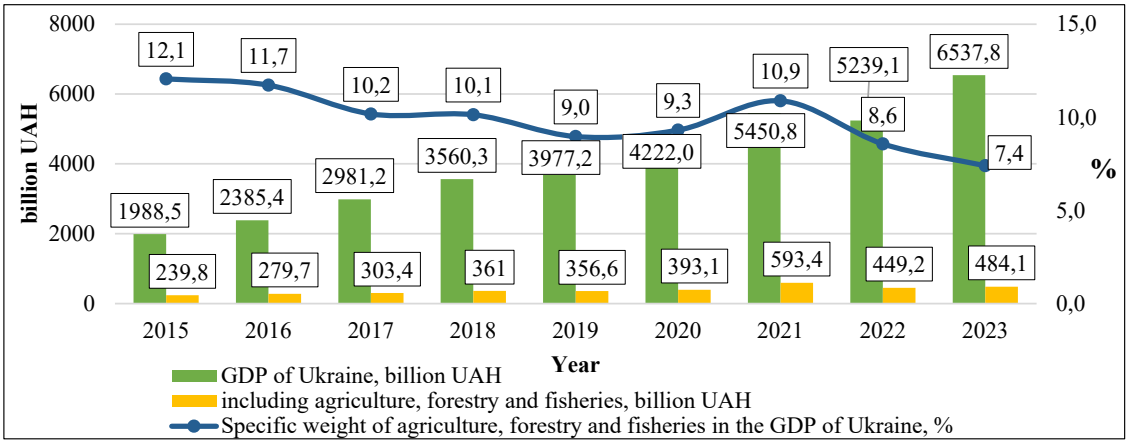

Figure 1. Dynamics of Ukraine's GDP and the share of agriculture in it in 2015-2023

Source: calculated and built by the authors on the basis of (State Statistics Service of Ukraine, 2023)

According to the State Statistics Service of Ukraine for 2015-2023, the share of agriculture in GDP (by production method) is the highest: 12.1% (239.8 billion UAH) in 2015, 11.7% (279.7 billion UAH) in 2016, and 10.9% (593.4 billion UAH) in 2021. However, in the last two years (2022-2023), this figure has decreased. Compared to the previous year, the share of agriculture in GDP in 2023, which reaches 484.1 billion UAH, decreased by 1.2%, and in 2022, which reaches 449.2 billion UAH, decreased by 2.3%.

Functionally, the business sector of the agro-industrial complex is quite successful in solving the main tasks of ensuring the country's food security. However, as a result of negative factors affecting the competitiveness of agricultural enterprises and specific conditions of agricultural activity, there was a reduction in active business entities in agriculture, forestry, and fisheries (Table 1).

Based on the results of the analysis, it was found that over the past 5 years in Ukraine, the number of active economic entities in agriculture, forestry and fishing decreased the most in 2020-2022 in comparison with the previous year. In particular, their number decreased by 2082 units in 2020, by 2565 units in 2021 and by 17522 units in 2022, the year when the war started. At the regional level, the number of agricultural producers also decreased, but not as significantly. Obviously, this is due to the fact that Vinnytsia is one of the leading agricultural regions, producing about 10% of Ukraine's agricultural products. Over the past 5 years, the number of business

Table 1

The number of actions of business entities in agriculture, forestry and fisheries in 2015-2022 in Ukraine and Vinnytsia Oblast

Year	Total, units	of them individual entrepreneurs	in % to the total indicator	Total, units	of them individual entrepreneurs	in % to the total indicator
	Ukraine			**Vinnytsia Oblast**		
2015	79284	32540	41,0	4939	2417	48,9
2016	74620	29622	39,7	4811	2266	47,1
2017	76593	26478	34,6	4535	1819	40,1
2018	76328	25824	33,8	4432	1621	36,6
2019	75450	25211	33,4	4406	1546	35,1
2020	73368	23916	32,6	4286	1443	33,7
2021	70803	23050	32,6	4196	1384	33,0
2022	53281	20437	38,4	4297	1400	32,5
Compared to the previous year (+, -)						
2018	-265	-654	-0,8	-103	-198	-3,5
2019	-878	-613	-0,4	-26	-75	-1,5
2020	-2082	-1295	-0,8	-120	-103	-1,4
2021	-2565	-866	0	-90	-59	-0,7
2022	-17522	-2613	5,8	101	16	-,05

Source: calculated and built by the authors on the basis of (State Statistics Service of Ukraine, 2022)

entities decreased the most in 2018 by 103 units, in 2020 by 120 units. The fact that their number will increase by 101 units in 2022 is positive. According to the authors, this happened at the expense of relocated enterprises and internally displaced persons engaged in agriculture in the Vinnytsia Oblast.

The share of agriculture in the country's GDP is confirmed by the positive dynamics of agricultural production until 2021 inclusive (excluding 2022), as characterised by the agricultural production index (Table 2).

The analysis has shown that in 2015-2022, the largest increases in gross agricultural production are observed in 2021 to 2020, which is 26.5% (including crop production increased by 34.7% and livestock production decreased by 2.1%); in 2018 compared to 2017, which is 10.4% (including a 13.1% increase in crop production and a 1% decrease in livestock production) and in 2016 compared to 2015, which is 11.1% (including a 14.3% increase in crop production and a 0.9% decrease in livestock production). In the context of the war, 2022 is characterised by the largest decline in the agricultural production index over the study period, which decreased by 41.4% compared to 2021. The dynamics of the agricultural production indices for 2015-2022 are driven by fluctuations in crop production rather than livestock production.

One of the indicators of the efficiency of agricultural enterprises is the level of profitability of production of the main types of relevant products, i.e., the ratio of profit (loss) from the sale of products to their full cost (Figure 2). A high level of profitability is the main indicator of an enterprise's efficient operation.

Against the background of the overall positive level of profitability in 2015-2020, the negative level of profitability for certain types of products can be considered as an exception, for example for potatoes (-3.2%) in 2016 and for sugar beet (11.4%, -15.4% and -13.5%) in 2018-2020. In 2020, compared to 2019, there is a positive trend in the production of plant products by agricultural enterprises, which is due to an increase in the production of certain agricultural crops of Ukraine, in particular cereals by 8.2%, sunflower seeds by 15.9% and open-ground vegetables by 1.3%.

Table 2

Agricultural production indices by category of farms in 2015-2022 (% to the previous year)

Indicator	2015	2016	2017	2018	2019	2020	2021	2022	Deviation, +/-	
									2022 /2021	2022 /2015
Farms of all categories										
Agricultural products, including:	95,2	106,3	97,8	108,2	101,4	89,9	116,4	75,0	-41,4	-20,2
crop production	94,8	109,1	97,1	110,2	101,8	87,9	122,6	72,0	-50,6	-22,8
livestock production	96,4	97,3	100,2	101,2	100,2	97,5	95,4	88,0	-7,4	-8,4
Enterprises										
Agricultural products, including:	128,3	94,8	109,7	112,0	102,7	88,0	122,3	72,0	-50,3	-56,3
crop production	134,9	94,5	112,4	113,6	102,5	85,8	127,8	68,5	-59,3	-66,4
livestock production	104,5	96,5	97,5	104,5	103,8	99,3	98,0	91,8	-6,2	-12,7

Source: calculated and built by the authors on the basis of (The Statistical Yearbook "Agriculture of Ukraine", 2022)

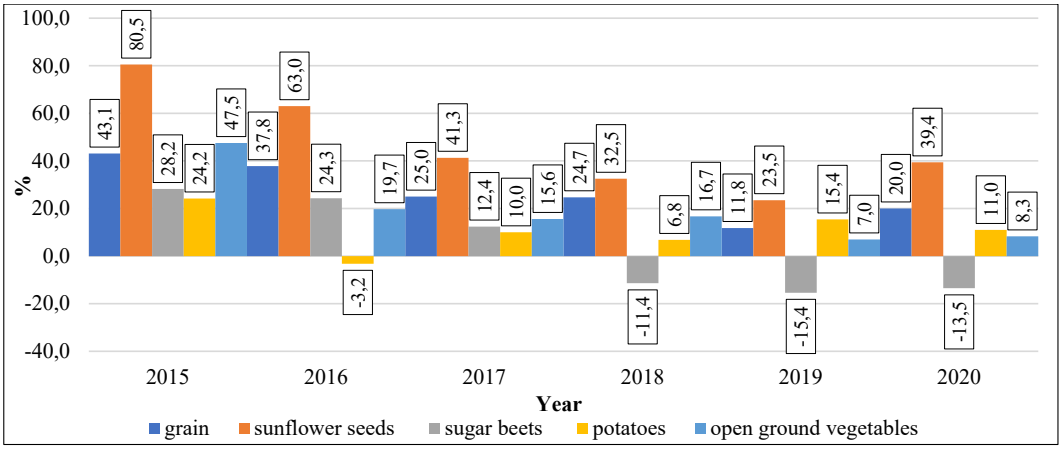

Figure 2. The level of profitability of crop production in Ukraine for 2015-2020, %

Note: data from 2021 are not provided by the State Statistics Service of Ukraine

Source: calculated and built by the authors on the basis of (State Statistics Service of Ukraine, 2020)

Today, the vast majority of Ukrainian farms grow crops on leased land, which accounts for over 95% of total land use. In the vast majority of cases, 45% of all contracts are concluded for 8-10 years, 17% – for more than 10 years, and 3% – for 1-3 years (Kaletnik, 2020). This is explained by the fact that farmers and entrepreneurs are unable to purchase agricultural land, and renting is one of the rational tools for securing land resources.

Livestock production remains unprofitable, due to the high production costs of animal products. The profitability of the production of animal products is negative for individual species throughout the period considered (Figure 3).

During the period 2015-2020, a consistently low level of profitability is observed for a significant number of types of livestock products. In particular, sheep and goat meat and beef meat are unprofitable (with the exception of 2017, with a profitability of 3.4%). Dairy products and pigmeat have been stably profitable throughout the period under study (with the exception of 2016, when profitability was -4.5%). The profitability indicator for the production of poultry meat and eggs fluctuates. The highest rate of profitability of poultry meat production was 7.0% and the lowest was -6.1%. The indicator of profitability of chicken eggs is characterised by strongly changing dynamics – its highest value was 60,9% in 2016 (which is the highest among all animal products), and the lowest was -23,5% in 2019.

According to the authors, the low level of profitability of livestock production is due to a number of reasons, including: rising production costs and, accordingly, prices for its sale; insufficient funding for the modernisation of the industry; increased costs of keeping animals (high prices for feed, equipment, energy); the risk of death of young animals, etc.

Therefore, the indicator of profitability of agricultural products is one of the factors of competitiveness of enterprises with a positive or negative impact.

Today, scientists identify a number of factors that affect the competitiveness of enterprises. In particular, they classify the factors into external and internal, controlled and uncontrolled, micro-, meso-, and macro-level factors, factors of product competitiveness and enterprise potential, etc.

In the framework of this study on the competitiveness of agricultural enterprises, it is appropriate to use micro-, meso-, macro- and meta-level factors (Table 3).

All four levels of factors affect all agricultural enterprises both positively and negatively. Taking into account the current economic conditions, the military actions on the territory of Ukraine, the economic crisis, it is worth revealing the main negative factors of influence, which in the first place can reduce the indicator of competitiveness. Unfortunately, they cannot be completely avoided, but having studied them, there is an opportunity to reduce, if not avoid, the force of their impact.

The main negative factors affecting the competitiveness of agricultural enterprises in Ukraine from the micro- to the meta-level include the following: loss of all or part of the business due to military threats; shortage of personnel due to mobilisation, internal migration, emigration; logistical problems with the supply of products and obtaining raw materials in the domestic and foreign markets with increased costs; problems with electricity supply; demand due to inflationary processes and a decline in the country's population's income; growing risks of recession in the European

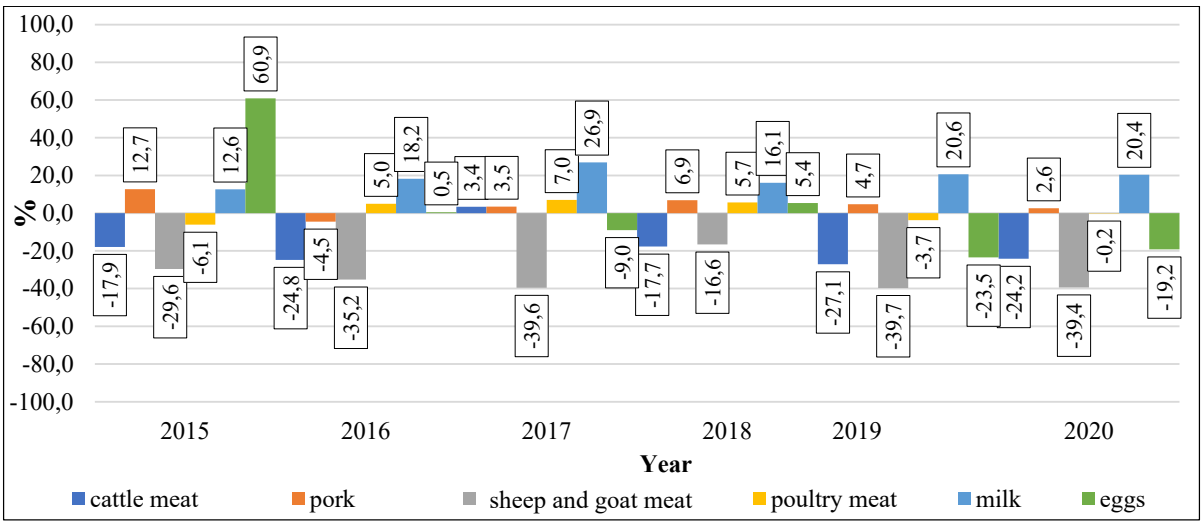

Figure 3. Profitability of livestock production in Ukraine in 2015-2020, %

Note: data from 2021 are not provided by the State Statistics Service of Ukraine

Source: calculated and built by the authors on the basis of (State Statistics Service of Ukraine, 2020)

Table 3

Factors influencing the competitiveness of agricultural enterprises

Impact level			
Micro-level	Meso-level	Macro-level	Meta-level *
Marketing activities at the enterprise	State of innovation activity	Level of effective consumer demand	Conditions of foreign economic activity, European integration processes*
Logistics activities at the enterprise*	Scientific and technical potential of the industry	Level of support for domestic producers	Global demand amid a shortage of crop and livestock products*
Natural, climatic and soil conditions*	Awareness of market conditions	Institutional policy of the state	Scientific and technological progress*
Staff qualifications and level of motivation	Competitor companies*	Inflation rate*	Logistics processes*
Material, technical and financial support of the enterprise	Material, technical and financial support of enterprises in the industry	Information technology (smart technology)*	Regulatory and legal support*
Innovative capacity of the enterprise*	Efficiency of the industry organisation	Financial, tax, credit policy of the state	Migration processes*
Production volumes, costs, specialisation and size of the enterprise	Terms of material and technical supply	Institutional support for innovation activities*	Military and political situation*
Quality of raw materials and semi-finished products*	Level of fertiliser supply	Standardisation of production and labelling of products*	Compliance of products with international standards*
Level of technology investment	Level of availability of plant protection products*	Social and environmental responsibility*	International trade tax liabilities*

Note: *authors' suggestion

Source: built by the authors on the basis of (Pakhucha, 2018; Kuznetsova, 2021; Pidvalna, 2022) and own research

Union and China; reluctance of most potential businessmen to do business with Ukrainian companies, including investment in Ukrainian crop and livestock production (Perehuda, 2022).

In order to reduce the impact of the existing negative factors on the competitiveness of an agricultural enterprise, it is necessary to develop and implement a management mechanism that would not only reduce the impact of negative factors, but also increase competitiveness in the innovation sphere. One of the components of this mechanism is the energy component, in particular, the production of biofuels from agricultural waste, which is a determining factor in ensuring energy independence of both the agricultural sector of the economy and the country as a whole. This is confirmed by the research of the team of authors, who claim that the use of agrobiomass as a raw material for the production of biofuel in Ukraine is becoming more and more popular and expanded, which is explained by the stable level of functioning of the agricultural sector of the economy (Pryshliak, 2022) (Figure 4).

The above data shows that the volume of agricultural waste in the country in the period from 2010 to 2020 ranged from 5.3 million tonnes to 12.4 million tonnes, which was from 1.15% to 2.94% of the total amount of waste generated. The share of agricultural waste generated has been gradually decreasing and in 2020 amounted to 1.15%.

One of the main advantages of using agrobiomass for energy is its versatility, both in terms of energy conversion technologies and methods of final use. Biomass can be used for energy purposes by direct combustion (wood chips, straw bales, pellets, briquettes), in processed liquid form (rapeseed oil esters, alcohols, liquid pyrolysis products) or as gaseous biofuels (biogas from agricultural and plant waste, sewage sludge water, organic fraction of solid household waste, gasification products of solid fuels). The use of biomass thus contributes to reducing dependence on exhaustible natural resources, as well as reducing the negative impact on the environment by replacing fossil fuels and reducing emissions of harmful substances into the atmosphere.

Intensifying the production and use of biofuels by agricultural enterprises is important in terms of ensuring energy security, reducing dependence on imported energy, creating additional sources of income for farmers, reducing emissions of harmful substances and contributing to environmental protection. This paper suggests considering the potential of biofuel production on the example of biogas (Figure 5).

In 2022, biogas production in Europe totalled 16.8 bcm, which is 8.9 bcm more than in 2011 and 0.1 bcm more than in 2021. Combined biogas and biomethane production in Europe in 2022 was 21 bcm. This exceeds Poland's entire domestic demand for natural gas and accounts for 6% of EU

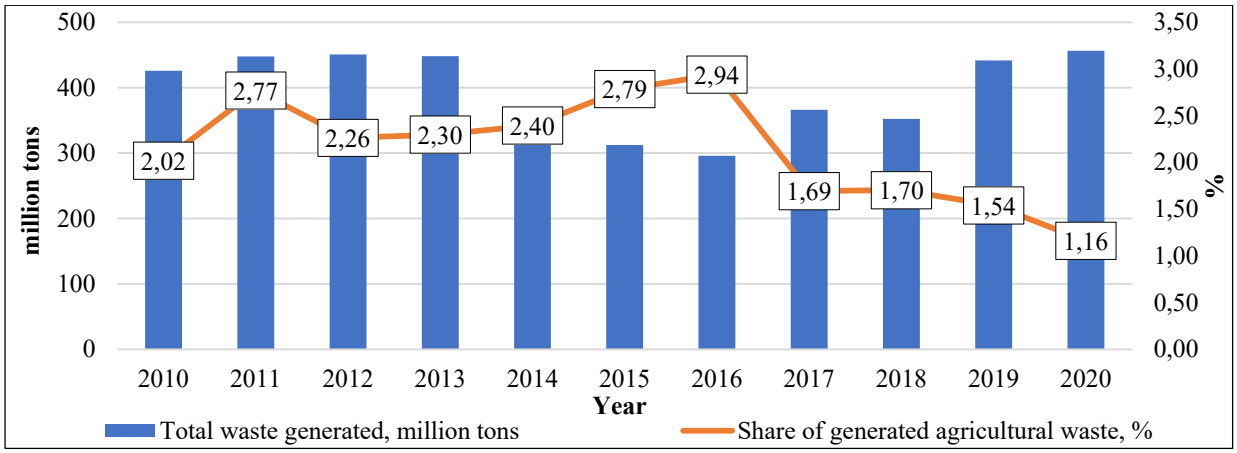

Figure 4. Dynamics of agricultural waste generation, 2010-2020, %

Source: calculated and built by the authors on the basis of (State Statistics Service of Ukraine, 2020)

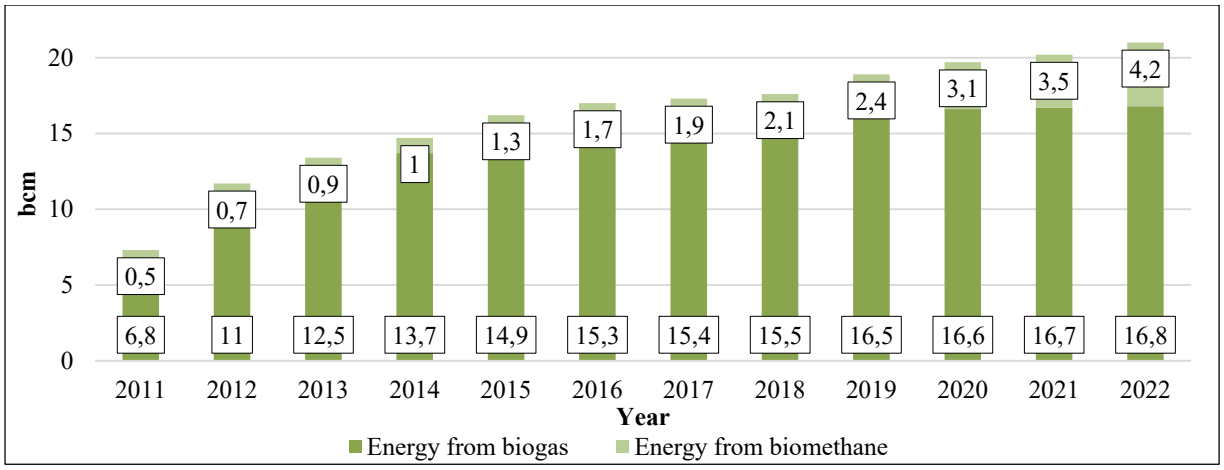

Figure 5. Biogas production in Europe (combined biogas and biomethane)

Source: EBA Statistical Report, 2023

natural gas consumption in 2022. Biomethane production alone increased from 3.5 bcm in 2021 to 4.2 bcm in 2022. In the case of Denmark, the share of biomethane in the gas network is close to 40%, and there are plans to increase this production to meet 100% of gas demand by 2030 (EBA Statistical Report, 2023).

Increasing the production of biogas and biomethane in Ukraine will reduce dependence on energy and fuel imports. The cultivation of energy crops for biogas production can stimulate the development of agriculture and provide additional sources of income for agricultural enterprises (Shpykuliak, Bilokinna, 2019). Therefore, Ukraine should adopt the experience of European countries in the production of biogas and biomethane to ensure energy independence of both economic entities and the country as a whole and to maximise the percentage of substitution of gas demand by 2030.

4. Innovative Mechanism for Improving the Competitiveness of Agro-Industrial Complex Enterprises

Any area of management activity of an enterprise, or rather the management of its individual components, which have their own specific sets of indicators, features and characteristics, requires the development of its own, unique type of management mechanism that would determine the interaction and functioning of the enterprise's elements. For example, the economic mechanism is reflected in the creation of a system of interrelated forms and methods of management of business entities; the business mechanism – ways, methods, forms and tools of influence on economic relations and processes; the organisational mechanism – rules and regulations that govern the behaviour of all elements of a business entity and ensure a "productive dialogue" between them; and

the legal mechanism – regulations, procedures, rules and mechanisms that govern its activities.

Conceptually, any mechanism is accompanied by a certain process (increase, improvement, provision, etc.) aimed at performing specific functions, without which the mechanism itself cannot exist a priori. At the same time, the same process should be provided with adequate resources to achieve its goals. This statement leads to the conclusion that in order to ensure the innovation process of business entities, in particular to accelerate the process of generating innovative ideas, the process of finding optimal innovative solutions, rational use of innovative potential, selection of a system of levers and incentives for regulating innovation, and so forth, the task of forming an effective mechanism for ensuring the management of innovative development of agricultural enterprises, i.e., an innovation mechanism, arises.

The authors believe that an innovative mechanism for improving the competitiveness of AIC enterprises is a system of clearly organised actions that lead to an improvement in the quality of functioning of an economic entity on the basis of accumulation of competitive advantages and bringing them to a qualitatively new level, giving them signs of innovation and new economic content.

Considering the proposed innovative mechanism from the standpoint of systems theory and system analysis, it can be presented in the form of a functional block, which is an element of control of the transformation process of a certain economic system X with its primary characteristics $\{x_1, x_2, \ldots, x_n\}$ at the entrance to the new system X^* with updated indicators $\{x_1^*, x_2^*, \ldots, x_n^*\}$ at the output (Figure 6).

The innovation mechanism acts as a "brain" that adjusts the business logic of an economic entity to achieve its goals, namely, to transform the initial state x into something different from the existing state, in particular, into $x+\Delta x$. According to the authors' vision, the formation of an innovative mechanism will allow solving a set of problems related to setting up business processes of a business entity to ensure successful transformation of the system from the initial state x to a new one - x^*.

The innovation mechanism in agriculture is not only a key factor in improving processes and products, but also a strategic opportunity to increase the competitiveness of agricultural enterprises. According to the authors, the synergistic combination of innovation and energy potentials is the most effective approach to achieving this goal, as it contributes not only to the integration of the latest technologies and methods into production, but also to optimising resource use and ensuring efficient production (Chikov, 2022a).

According to the authors, innovative and energy potentials represent key components of a successful mechanism of agricultural development. The interaction between these two elements creates a favourable platform for sustainable growth and increasing the competitiveness of agribusiness enterprises. In essence, the mechanism posits that innovations and energy resources interact with one another, reinforcing their influence and promoting the efficient use of resources in all aspects of economic activity. Together, they create favourable conditions for the sustainable development of agribusiness enterprises, ensuring their competitiveness and ability to adapt to changes in a global dynamic environment.

Consequently, the objective of the innovation mechanism is to modify the business environment of the economic entity in order to achieve the cumulative effect of the effective utilisation of innovative and energy potentials. In this context, it is important to note that the cumulative effect refers to the phenomenon whereby the combined influence of innovative and energy resources exceeds the simple effect of each of them separately.

The implementation of an innovative mechanism to improve the competitiveness of agribusiness enterprises includes several key stages that promote the efficient use of resources and ensure sustainable development in this area (Figure 7).

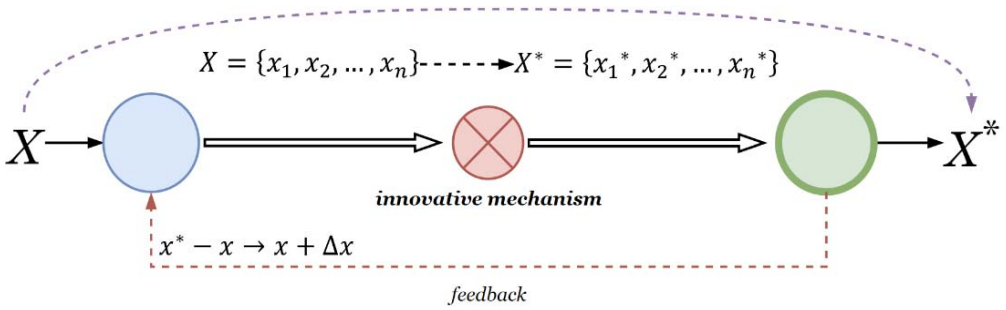

Figure 6. Linear model of an innovative mechanism for improving the competitiveness of agricultural enterprises

Source: authors' development

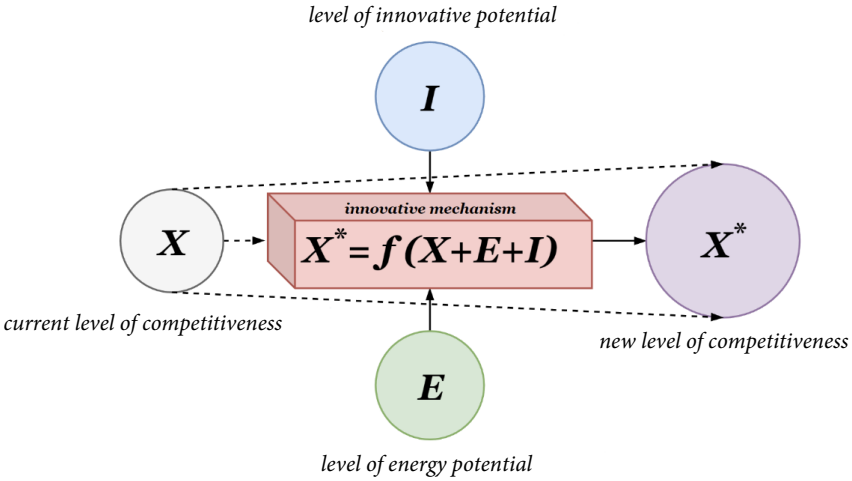

Figure 7. Functional model of an innovative mechanism for improving the competitiveness of agricultural enterprises

Source: authors' development

The first stage is the diagnosis of the current level of competitiveness of agro-industrial enterprises. The assessment of competitiveness of business entities, in particular enterprises of the agro-industrial complex, can solve a number of tasks, including: determining the level of efficiency of functioning at a given moment, tracing the trends of changes in the business environment during the studied period, identifying "bottlenecks" and reserves for increasing the economic stability of enterprises (Sitkovska, 2019).

The second stage is the assessment of the innovation potential of agricultural enterprises. It involves analysing the financial resources of the business entity for their sufficiency to cover current expenses and form reserves in the context of ensuring innovation.

The third stage is the determination of the energy potential of agricultural enterprises. This involves assessing the energy efficiency of production processes, the use of renewable energy sources, as well as opportunities to reduce emissions and introduce energy-saving technologies. Efficient use of energy resources can significantly reduce the costs of enterprises and increase their competitiveness in the market.

In general, an innovative mechanism for improving the competitiveness of agricultural enterprises involves systematic analysis, strategic planning and effective management of resources to optimise them. Only in this way will enterprises be able to successfully compete in the market and ensure sustainable development of the agricultural sector of the economy.

Within the framework of the first stage, the assessment of competitiveness consists in recording the results of the competitive struggle of enterprises in the form of competitive advantages in comparison with their competitors. Taking into account the results of own researches described in works (Chikov, 2023), it is proposed to diagnose the competitiveness of agribusiness enterprises using the author's model based on the principles of artificial intelligence. Taking into account studies, which prove that models based on artificial intelligence allow to solve problems based on incomplete, "noisy", distorted information, this will allow to obtain reliable and objective results, reflecting the real state of functioning agribusiness enterprises (Matviychuk, 2010; Ruzakova, Yurchuk, 2021).

Thus, using the open financial statements of business entities (forms No. 1 and No. 2), the authors calculated the competitiveness indicators of the studied enterprises of the agricultural sector of Vinnytsia region, whose main economic activity according to Classification of Economic Activities 01.11 is the cultivation of cereals (except rice), legumes and oilseeds. To interpret the data obtained, the authors' three-level Harrington scale was used (Table 4).

In the second stage, the competitiveness of agro-industrial enterprises must be considered in the context of their ability not only to adapt to changes in market conditions, but also to actively implement innovations. In particular, the competitiveness of enterprises of the agro-industrial complex should also be assessed on the basis of the existence of the innovation potential of the enterprise, i.e., that which is a determinant of technological and non-technological innovations. Innovative potential is a set of different types of resources that can be used to ensure the implementation of innovative activities (Chikov, 2022b).

According to the authors' methodology described in the work (Chikov, 2022b), the innovation potential of the studied enterprises of the Vinnytsia region was assessed. The results of the assessment help enterprises to determine their competitive advantages and risks associated with innovative activities and

Table 4

The level of competitiveness of the studied enterprises of the agricultural sector of Vinnytsia Oblast

Enterprise	Year								
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Agricultural complex "Zelena Dolyna"	0,502	0,822	0,615	0,482	0,337	0,273	0,380	0,343	0,446
PJSC "Dashkivtsi"	0,710	0,362	0,605	0,391	0,413	0,437	0,529	0,493	0,521
LLC "Selyshchanske"	0,758	0,520	0,314	0,541	0,289	0,310	0,331	0,412	0,422
FE "Yavir"	0,226	0,793	0,448	0,459	0,379	0,337	0,281	0,460	0,515
FE "IRYNA – O.T"	0,524	0,569	0,534	0,469	0,250	0,478	0,477	0,394	0,421

Source: authors' development

to make informed decisions on improving their competitiveness in the market.

The model is presented in the form of a three-component model for determining the type of financial sustainability, which is based on a system of absolute indicators of stocks' availability by sources of their formation (1):

$$\begin{cases} IP^* = \left[IP_1\left(\pm K_1\right)\right], \left[IP_2\left(\pm K_2\right)\right], \left[IP_3\left(\pm K_3\right)\right] \\ IP_i\left(K_i\right) = \begin{cases} 1, K_i \geq 0 \\ 0, K_i < 0 \end{cases} \end{cases} \quad (1)$$

where, IP^* is the level of innovation potential; $\pm K_1$ – surplus (+) or shortage (-) of own sources of financing; $\pm K_2$ – surplus (+) or shortage (-) of own and long-term loan funds; $\pm K_3$ – surplus (+) or shortage (-) of the total amount of financial resources; $K_{1,2,3}$ – partial model components.

The combination of partial components of the model provides a complete picture of the innovation potential of agribusiness enterprises. The results of the assessment help the company's management to identify the strengths and weaknesses of its innovation activities and develop strategies for further development.

Below is a scheme for assessing the innovation potential of agricultural and agricultural enterprises (Table 5).

Thus, according to the described approach, the level of innovation potential of the studied enterprises in Vinnytsia region for 2015-2023 was determined (Table 6).

With a high level of innovation potential, the enterprise is characterised by a high level of provision of its own resources, accordingly, the cost of carrying out innovative activities can be covered at the expense of free funds without loans. Here, the management can consider the implementation of incremental or improvement innovations, which can be carried out using the enterprise's own sources of finance, with minimal involvement of funds from external sources of finance.

With an average level of innovation potential, an enterprise is characterised by an average level of own resources. In this case, the most optimal approach is to finance activities related to the development

Table 5

Scheme for assessing the innovation potential of agricultural enterprises

Type of combination of model components	Level of innovation potential	Interpretation by the Harrington scale
$IP = \{1,1,1\} \rightarrow$	high level	1
$IP = \{0,1,1\} \rightarrow$	medium level	0,67
$IP = \{0,0,1\} \rightarrow$	low level	0,33
$IP = \{0,0,0\} \rightarrow$	zero	0

Source: authors' development

Table 6

The level of innovation potential of the studied agricultural enterprises of Vinnytsia Oblast

Enterprise	Year								
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Agricultural complex "Zelena Dolyna"	1	1	1	0,67	1	1	1	0,67	1
PJSC "Dashkivtsi"	1	0,33	1	1	1	1	0,67	0,33	1
LLC "Selyshchanske"	0,67	1	1	1	1	1	0,67	0,33	0,33
FE "Yavir"	0	0,33	0	0,67	1	0,33	0,33	0,67	1
FE "IRYNA – O.T"	1	1	0,67	0,67	1	1	0,67	0,67	0,33

Source: authors' development

and dissemination of step-by-step innovations. The costs of this type of innovation activity can be fully covered by the company's own sources of funding. Implementation of improvement innovations requires additional funds from external sources of financing.

With a low level of innovation potential, an enterprise is characterised by a low level of own resources, and the issue of innovation can only be considered in terms of financing and implementing step-by-step innovations. Otherwise, the company risks becoming bankrupt.

The third stage involves assessing the bioenergy potential of biofuel production as a basis for implementing sustainable development strategies in the energy sector. For this purpose, the authors calculated the agrobiomass potential of the studied enterprises in Vinnytsia Oblast. The obtained results became the basis for further planning and implementation of biofuel production projects aimed at optimising the use of natural resources, reducing the negative impact on the environment and increasing the competitiveness of agribusiness enterprises.

The analysis of literature sources has made it possible to state that there is no single standard or methodology for assessing the bioenergy potential of biofuel production. However, research by Ukrainian scientists (Kaletnyk, Goncharuk, 2013; Hryhoruk, 2020; Lohosha, 2022; Honcharuk, 2023a; Honcharuk, 2023b; Honcharuk, Yemchyk, 2024; Honcharuk, 2024b) made it possible to form a methodology for assessing the energy potential, which takes into account the specifics of local conditions and features of the biofuel market (2):

$$E = (E_{cw} + E_{lw} + E_{ac} + E_{tc}) * K_{be}, \quad (2)$$

where E_{cw} is the energy potential of crop waste; E_{lw} is energy potential of livestock waste; E_{ac} is energy potential of actual energy crops; E_{tc} is energy potential of traditional energy crops; K_{be} is the coefficient for converting a tonne of fuel equivalent to a barrel of oil equivalent (1 tonne of fuel equivalent ≈ 0.714 barrels of oil equivalent (BOE)).

Thus, on the basis of the calculations, the indicators of the energy potential of the studied enterprises were obtained. For the convenience of interpreting the data on the Harrington scale, the results were standardised in the range of 0;1 (Table 7).

According to the data obtained, it can be concluded that the level of energy potential of the studied enterprises reflects significant fluctuations during the given observation period. Some enterprises show more stable trends than others, which are characterised by greater changes in the level of energy potential from year to year. Such fluctuations may affect the efficiency and stability of the production processes and the overall productivity of the energy supply of the enterprises.

These fluctuations in the level of energy potential can be caused by factors such as changes in energy efficiency management, investment in new technologies, the use of alternative energy sources or even changes in production volumes. In order to achieve sustainable growth and market competitiveness, companies must actively work to optimise their energy potential and consider the economic and environmental aspects of energy resource management.

Fuzzy logic methods were used to create a fuzzy knowledge base for the mathematical representation of the results of the assessment of the level of competitiveness, innovation and energy potential of enterprises of the agro-industrial complex in order to identify directions for increasing their competitiveness (Honcharuk, 2020) (Table 8).

On the basis of the received data, a polycomponent decision-making system for various combinations of the values of the components of the innovation mechanism was built and the direction of increasing the competitiveness of the enterprise was determined (on the example of the Agricultural complex "Zelena Dolyna") (Figure 8).

In the proposed three-dimensional spatial model, where the Ox axis reflects the level of competitiveness (X), the Oy axis – the level of energy potential (E), and the Oz axis – innovation potential (I), 27 quadrants are formed, each of which corresponds to a combination of these three factors. Each quadrant represents a unique context with its own approach to the strategic management of agricultural enterprises to improve their competitiveness.

Table 7
The level of energy potential of the studied agricultural enterprises of Vinnytsia Oblast

Enterprise	Year								
	2015	2016	2017	2018	2019	2020	2021	2022	2023
Agricultural complex "Zelena Dolyna"	0,15	0,98	0,24	0,87	0,00	0,66	1,00	0,28	0,17
PJSC "Dashkivtsi"	1,00	0,47	0,47	0,42	0,65	0,40	0,77	0,00	0,98
LLC "Selyshchanske"	0,67	0,09	0,48	0,69	0,00	1,00	0,26	0,74	0,06
FE "Yavir"	0,50	0,57	0,00	0,64	1,00	0,57	0,96	0,21	0,71
FE "IRYNA – O.T"	0,95	1,00	0,98	0,00	0,38	0,76	0,10	0,53	0,38

Source: authors' development

Table 8

Fuzzy knowledge base for determining the directions of increasing the competitiveness of agricultural enterprises

Rule	Competitiveness level	Innovative potential level	Energy potential level	Quadrant
	X	I	E	
1	L	L	L	A
2	L	L	M	B
…	…	…	…	…
16	M	H	L	P
…	…	…	…	…
26	H	H	M	Z
27	H	H	H	AA

Note: L – low level; M – medium level; H – high level

Source: authors' development

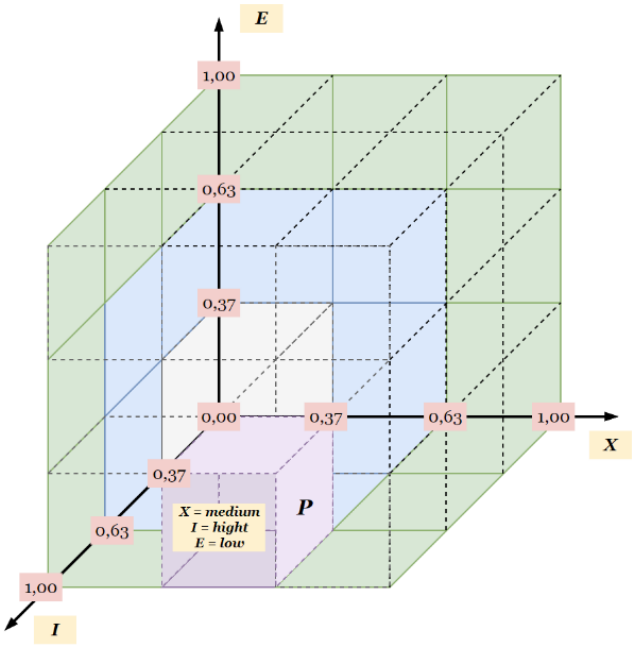

Figure 8. Polycomponent model for determining the directions of increasing the competitiveness of agricultural enterprises

Source: authors' development

For example, within the framework of the "P" quadrant, which is cumulative with regard to the indicators of the Agricultural complex "Zelena Dolyna", it is optimal for the company to implement a strategy of market leadership in innovation, to create an innovative environment, as well as to use innovative technologies to optimise production processes and reduce energy costs. Particular attention should be paid to intensifying research into technologies for processing agricultural waste into biofuels. This may include finding new recycling methods and processes, using biotechnology to optimise production and improve the quality of biofuels, and developing efficient technological solutions to reduce energy costs in the process.

Looking at the other quadrants provides a deeper understanding of the relationship between competitiveness, innovation capacity and energy potential. In particular, in quadrants where competitiveness is high but energy potential is low, strategies may focus on finding alternative sources of energy or improving the efficiency of the use of existing resources. In situations where innovation capacity is high but competitiveness is low, strategies may focus on creating and introducing new products or services that will gain an advantage in the marketplace. Where all three factors are low, strategies may include stimulating research and development, reforming energy policies and actively supporting innovation.

5. Conclusions

In the framework of the study of ensuring the competitiveness of agro-industrial enterprises, four levels of factors have been allocated, in particular, micro-, meso-, macro- and meta-levels. It is substantiated that regardless of the size of the enterprise and methods of conducting foreign economic activity, the formed levels of factors directly affect economic activity. This is justified by the fact that even small enterprises in the agricultural sector, which mostly operate at the regional level, should be aware of the impact of meso- and macroeconomic factors, such as legislative norms, market trends, and economic policy of the state. On the other hand, large enterprises engaged in international trade must also take into account microeconomic aspects such as resource management and technological competitiveness. Thus, the formation of competitiveness of agribusiness enterprises is a complex process that takes into account a wide range of factors at all levels of their operation. This gave a comprehensive view of the various aspects that affect the competitiveness of agribusiness enterprises and allowed to formulate the theoretical and methodological foundations of an innovative mechanism aimed at improving the competitiveness of agribusiness enterprises at all levels of their economic relations.

With a view to reducing the impact of negative factors on the competitiveness of agricultural enterprises, the authors propose a conceptual model of an innovation mechanism that will not only reduce the impact of negative factors, but also ensure an increase in the competitiveness of economic entities. The authors define the concept of an innovative mechanism for improving the competitiveness of agro-industrial enterprises as a system of clearly organised actions that lead to an improvement in the quality of functioning of an economic entity on the basis of accumulation of competitive advantages and bringing them to a qualitatively new level, giving them signs of innovation and new economic content. It is proposed to consider the innovative mechanism for improving the competitiveness of agro-industrial enterprises through the prism of synergy of three key components: the current level of competitiveness, innovation and energy potential. The necessity of combining these three components is that each of them plays an important role in the development of an enterprise, but their full synergistic impact can be achieved only if they interact and mutually reinforce each other.

The synergy between these components must be ensured: 1) integration of innovations into production processes to ensure efficient use of resources and increase productivity; 2) use of energy-efficient technologies and alternative energy sources to reduce costs and negative environmental impact; 3) development of strategies and programmes aimed at improving staff skills and stimulating their creativity and initiative in implementing innovations; 4) creation of a favourable ecosystem for the development of innovations in agriculture, including support from the state, research institutions and the business environment.

This can help to increase the competitiveness of agricultural enterprises by optimising resources, introducing the latest technologies and ensuring sustainable development.

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