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Economic and mathematical approaches to the organisation of rational feeding of pigs

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► **Abstract.** In the context of increasing demands for food security, production efficiency, and sustainable agricultural development, economic and mathematical approaches to organising rational pig feeding were becoming increasingly relevant as tools for making sound management decisions in the livestock sector. The aim of this article was to develop and substantiate economic and mathematical models and methods for optimising the pig feeding process, taking into account the biological needs of animals, the efficient use of feed resources, and the principles of sustainable development in the pig industry. The study used general and specific methods of economic analysis: monographic, analysis and synthesis, dialectical, statistical, and abstract-logical methods. The results presented an overview of pork production in the world and in Ukraine, particularly for the period 2015-2023. A monitoring of pork prices was conducted for January 2023-March 2025. The main directions for the development of feed production and optimisation of pig feeding were outlined to ensure sustainable development of the industry in large-scale, farm, and household operations. The principles for forming an optimised pig diet under high-performance production conditions were identified. Equations for optimising the diet based on nutrient composition and dry matter content were calculated. The permissible ranges of feed ingredients were determined considering pigs' requirements for metabolisable energy, crude and digestible protein, amino acids (lysine, methionine + cystine, tryptophan), crude fiber, dry matter, calcium, and phosphorus. Optimisation of the feeding process made it possible to minimise the cost of the diet. For the grower group of pigs, the following feeding composition was recommended: wheat – 0.5 kg, barley – 0.3 kg, triticale – 0.3 kg, soybean meal – 0.481 kg, and Nutrimin premix – 0.068 kg. It was determined that the cost of the daily diet was UAH 16.09, or UAH 9.76 per 1 kg, and the diet was balanced in terms of nutrients and microelements

► **Keywords:** pig farming; balanced diet; optimised feeding; economic analysis model; concentrated feeds

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▸ Introduction

Rational pig feeding was a key factor in increasing productivity, economic efficiency and rational use of resources in livestock farming. Modern pig farming faced limited resources, unstable pricing policies, rising costs and product quality requirements. Additional risks were created by wars, economic instability and climate change. Livestock farming, in particular pig farming, was a strategic direction for food security, providing the population with high-quality protein products and contributing to the development of the agrarian economy. Scientific substantiation of economic and mathematical approaches to rational pig feeding was an important factor in increasing the efficiency and competitiveness of the industry, ensuring food security and sustainable development of the agro-industrial complex in conditions of limited resources and a changing environment.

The impact of pig farming on the well-being of the population was rather controversial, as it combined both positive and negative factors. Among the positive factors were innovations, the transition to European quality standards and intensification of foreign economic activity. On the other hand, the development of the industry was hampered by environmental risks, health threats, an unfavourable epizootic situation, the dominance of agroholdings and a low level of state support. V. Adamyk *et al.* (2019) emphasised that pig farming was a strategic sector of the agricultural sector, the effectiveness of which depended on innovation, compliance with quality standards, biosecurity and support for small producers, and its development required an integrated approach that combined economic, social and environmental factors to increase the competitiveness and sustainability of the industry. Y. Wang *et al.* (2024) studied the impact of including food waste in animal diets on their performance. The results of the study showed that alternative feed sources have significant potential and opened up opportunities for economic analysis modeling of optimal pig diets, taking into account the efficiency and safety of feeding. This included optimising animal nutrient intake, reducing waste and improving feed quality, while meeting safety standards. M. Balehegn *et al.* (2020) noted that growing demand for animal products in low- and middle-income countries created opportunities for producer welfare and food security, but limited supply and high feed costs constrain livestock development. The authors proposed strategies to improve the supply of quality feed, taking into account biophysical, socio-economic and technological constraints. The study of V. Maksym *et al.* (2022) assessed the economic efficiency of pig farming in Ukraine by modeling the impact of factors such as feed costs, market prices, and scale of production. Profitability in 2020 was 70%, but decreased by 2022 due to increasing feed and energy costs. Optimisation strategies were proposed to increase efficiency and profitability, taking into account market and technological conditions.

Researchers M. Davoudkhani *et al.* (2020) proposed an economic optimisation of pig feeding and transportation strategies taking into account individual biological characteristics of animals. The use of an individual bioeconomic model and an evolutionary algorithm allowed to increase the profitability of production and showed that the integrated optimisation of both strategies is more effective than separate planning. This approach emphasised the importance of economic and mathematical methods for the rational organisation of pig feeding and increasing production efficiency. M.M. Misiura *et al.* (2021) proposed a Bayesian approach to compare models of rational feeding of pigs during the growing and fattening periods. The authors proved that the use of this model contributes to increasing the accuracy of determining the individual nutrient needs of animals, which ensured the optimisation of rations and reduction of feed costs. I. Nesterchuk & O. Yurchenko (2022) emphasised that wartime conditions significantly changed the economic parameters of pig farming in Ukraine, in particular, the structure of production, the level of costs and price dynamics. Such challenges required the use of economic and mathematical approaches to optimise production processes, including the organisation of rational feeding, in order to increase the efficiency and sustainability of the industry.

V. Petrychenko *et al.* (2021) emphasised that the Ukraine had significant potential for the formation of a competitive market for high-protein feeds due to favourable soil and climatic conditions, logistics and developed infrastructure. Scientists emphasised the importance of developing industrial production and organic technologies in the feed sector, as well as improving legislative support in accordance with European standards. I. Verbych & H. Bratkovska (2020) substantiated the usefulness of replacing sunflower meal with soybean feed in the diets of young pigs: animals demonstrated higher average daily gains and better slaughter yield, while feeding efficiency increased due to reduced feed costs per unit of gain. In addition, assessment of the quality of the final product revealed advantages in groups of animals that received soy products, confirming their ability to increase the organoleptic characteristics of the product. K. Pavlova *et al.* (2024) proposed a mathematical modeling that allowed for the least cost-effective formulation of a balanced ration of hay and silage, in accordance with the requirements of the quality and quantity of feed, taking into account the real production process. This model, tested on livestock data in Bulgaria, illustrated the potential of economic and mathematical approaches for optimising balanced feeding, in particular, when forming a pig ration, where the main thing was to minimise feed costs and maximise production efficiency. Scientists K. Syrovatko & V. Vuhliar (2021) substantiated the effect of essential oil supplements on the productivity of young pigs, in particular on the average daily weight gain and nutrient absorption. The results indicated increasing the efficiency of pig breeding and improving the state of the gastrointestinal microflora. The purpose of the research was to develop and scientifically substantiate economic analysis models and methods aimed at optimising the process of feeding pigs, taking into account their biological needs, rational use of feed resources, and ensuring sustainable development of the pig industry.

▸Materials and methods

The study used both general and special methods of economic analysis, which ensured a comprehensive study of

the subject of the research. In particular, the monographic method was used for a deep theoretical analysis of the problem, methods of analysis and synthesis – for establishing relationships between individual economic indicators, the abstract-logical method – for formulating conclusions and generalisations. The information base for the analysis of the state of production in Ukraine of certain types of meat was data from the State Statistics Service of Ukraine (n.d.). The period of 2015-2024 was chosen for the analysis of meat and pork production in Ukraine, since it covered key structural transformations of the industry that occurred under the influence of economic crises, integration processes, and military challenges. Monitoring of pork prices was carried out according to the data of Minfin (2025). The dynamics of pork prices in Ukraine for 2023-2025 was used to provide the economic analysis model with relevant market data in the context of military challenges, price fluctuations, and changes in import dynamics. The source of statistical data on the global development of pig farming in the world was information from the reports of Research and Markets (2025), data from M. Shahbandeh (2025) and the United States Department of Agriculture Foreign Agricultural Service (2025).

The types of feed and their structure in the model were selected based on the recommendations of scientists from the Institute of Feed Research and Agriculture of Podillia of NAAS (Petrychenko & Korniichuk, 2023). The main restrictions in model were the conditions for providing pigs with all the necessary nutrients: metabolisable energy, crude protein, digestible protein, lysine, methionine + cystine, tryptophan, crude fiber, dry matter, calcium, phosphorus. To build an optimisation model, the following notations were introduced:

$$\sum_{j \epsilon N} u_{ij} x_j \geq b_i \, (i \epsilon_{Jn}), \quad (1)$$

where i – restriction index, indicating the ordinal number of the feeding element; j – variable index, indicating the ordinal number of the type of feed in the diet; u_{ij} – content of the nutrient element of the i-th type in a unit (1 kg) of the j-th type of feed; x_i – the desired amount of feed of the j-th type included in the diet; b_j – the required amount of the i-th type of nutrient in the diet according to the norm.

To form the ration in the model, the feeding standards for pigs of the grower group were used according to the data from the study of H. Bogdanov *et al.* (2012). The task of optimising a complete mixed ration for feeding pigs of the grower group, included the following parameters: the weight – 30-65 kg; age – 2.5-4.0 months; average daily gain – 750-900 g; type of fattening – meat, type of feeding – concentrate. The diet was optimised by the minimum cost criterion with mandatory compliance with feeding standards, nutrient content and ratio of individual feeds and their groups for a modular pig farm in conditions of the Right Bank Forest-Steppe of Ukraine. The diet was formed based on the results of research by scientists from the Institute of Feed Research and Agriculture of Podillia of NAAS, in particular T. Prudyus *et al.* (2025). The study was conducted in compliance with the requirements ARRIVE (2020).

▸ Results and Discussion

Pork production and the dynamics of the pig industry have a significant impact on ensuring global food security (Maksym *et al.*, 2020). Rational feeding of pigs was a key factor in increasing productivity, economic efficiency and sustainable use of resources in animal husbandry, especially in the context of growing demands for food security, sustainable development and market competition. Limited resources, fluctuations in feed prices and the need to reduce costs made it urgent to implement economic and mathematical approaches to optimise rations taking into account the biological needs of animals, economic parameters of production and changes in the external environment. The pig sector was subject to a large body of EU legislation covering various aspects. Environmental protection, food safety, and public health were addressed by Council Directive No. 98/58/EC (1998), Council Directive No. 2008/120/EC, 2008), and Regulation (EC) No. 178/2002 (2002). Regulations also covered organic production, animal health, and welfare (Commission Recommendation (EU) No. 2016/336, 2016). The European Pigmeat Reflection Group provided further recommendations for the sector (European Commision, 2022), in particular offered strategic guidance to improve sustainability, competitiveness, and welfare in the EU pig sector. However, evidence suggested that EU pig welfare rules were not being sufficiently complied with. The development of animal husbandry provided the population with high-quality products, and the demand for pork was growing, which made the industry attractive to investors. So, the modern economic and mathematical approaches allowed not only to improve the production structure and reduce feed costs, but also to increase the productivity and quality of the final product, in particular by replacing sunflower meal with soy products and optimising the ratios of feed components in rations. This approach emphasised the need for scientifically based formulation of pig rations to maximise efficiency and ensure sustainable development of the industry.

The development of livestock farming largely depended on the creation of a sustainable feed base, which contributed to the increase in livestock population, improving the quality and economic profitability of animal products. Analysis of data for 2020-2024 showed that local producers were becoming a certain guarantee of the state's food security. In addition, their products had the same quality as similar food products from large Ukrainian and European manufacturers (State Statistics Service of Ukraine, n.d.). The primary basis of feed production was the use of highly productive varieties of feed crops adapted to the conditions of different natural and climatic zones of Ukraine. Global trends in natural vegetation change required appropriate breeding developments to adapt perennial and annual grasses to environmental conditions. Ukraine, as one of the world's leading producers and exporters of forage grain crops, legumes, sunflower, soybeans, rapeseed and other valuable raw materials for feed production, had significant untapped potential for the pig breeding industry (Maksym *et al.*, 2022). Researchers T. Soleimani & H. Gilbert (2021) noted that the need of efficiency improvement was the main goal of increasing the sustainability of pig farming from the economic and environmental points of view.

Efficiency of feeds was one of the most important aspects of successful pig farming. Improving pig feeding

efficiency will bring three key benefits to pig producers: increase in pig productivity, shortening production cycles and reduced costs. As a result, profitability will increase, waste levels and environmental impact will be reduced, contributing to the sustainable development of the industry (Rooney, 2023). Efficient pork production was becoming a key factor in the profitability of the industry, especially in the context of digital technologies and precision farming. F. Leen *et al.* (2017) emphasised that economic optimisation involved determining the best input-output ratio for maximum profit. In intensive pig production, replacement management played an important role: the terms of the end of fattening period affected the time of putting in operation new batches of piglets and shaped the annual volume of production. Agricultural enterprises having weak competitive rates in pig farming can increase efficiency and strengthen their market positions through technological modernisation, investments in their own processing facilities and sales, development of organic production, and integration with meat processing enterprises and chain stores. Achieving competitiveness was possible through innovative technical re-equipment, cost reduction, mergers with more powerful players, or exit from the market (Samoilyk *et al.*, 2021).

According to the Global Pork Market report, the global pork market was projected to reach 168.5 million tons by 2030, with a 4.1% average annual growth over the period of 2024-2030. In 2024, the global pork market was 132.5 million tons (Research and Markets, 2025). Pig farming was developing in regions with wide access to grain and protein sources. According to the United States Department of Agriculture Foreign Agricultural Service (2025), in 2024 the global pig population exceeded 759 million heads, which was 2.4% less than in 2023. China leads the world in pork production, producing more than the United States and Europe together. China had the largest pig population of any country, with over 430 million heads as of April 2024 (Shahbandeh, 2025). Brazil was the largest pork producer, and Asian countries were the leading pork consumers. Japan, China, Mexico, the United Kingdom, South Korea, the United States, Hong Kong and the Philippines were the largest pork exporters (Kim *et al.*, 2024). Ukraine had the potential to develop pig farming even under martial law. Given modern challenges, it was advisable to create a strategic programme to increase the profitability of the industry based on attracting local and foreign investments to ensure the availability of pork for the population. The opinion of N. Hurzhii *et al.* (2022) about the feasibility of changing the vector of foreign trade by reducing grain exports in favour of pork and allocating an effective export niche for the development of pig farming was supported. Pork production in Ukraine showed a fluctuating trend: after a decrease from 760 thousand tons in 2015 to 697 thousand tons in 2020, there was a partial recovery to 672 thousand tons in 2024, which emphasised its importance for the stability of the meat market. At the same time, beef production had decreased, while poultry meat continued to grow, remaining the main driver of the total volume. The general trend indicated a shift in the production structure towards more productive and profitable types of meat with a gradual recovery of pork volumes (Fig. 1).

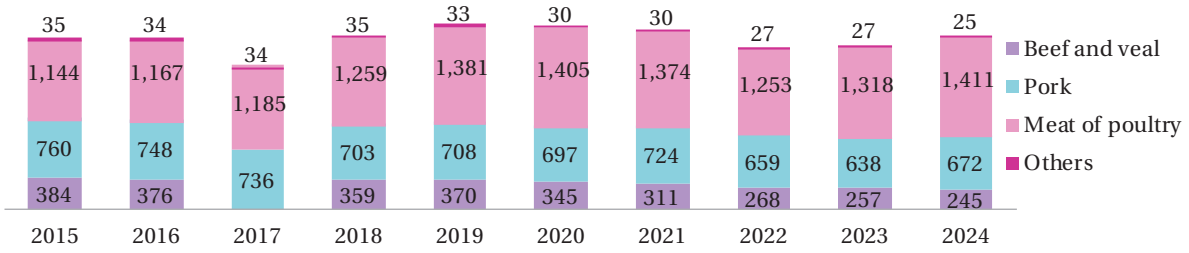

Figure 1. Dynamics of farm animal meat production in Ukraine, 2015-2024 (in slaughter weight, thousand tons)
Source: based on State Statistics Service of Ukraine (n.d.)

The pig industry accounts for about 30% of the supply of Ukrainians with meat products. During 2013-2022, there was a decrease in the number of pig livestock (Fig. 2), in 2023 it amounted to 4948.3 thousand heads, which is 2628.4 thousand heads or 34.7% less than in 2013. The decrease in pig population occurred both in households (by 2239.6 thousand heads, or 55.4%) and in agricultural enterprises (by 764.3 thousand heads, or 19.7%). Pork production in households decreased significantly (by 134.7 thousand tons, or 34.9%).

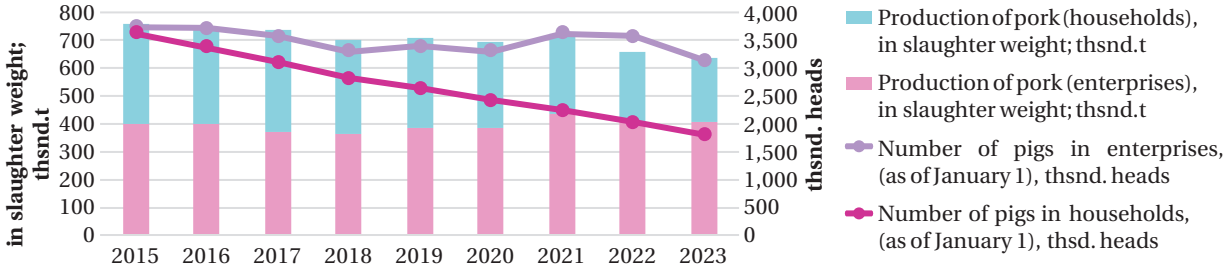

Figure 2. Status and development of pig farming in Ukraine, 2015-2023
Source: based on State Statistics Service of Ukraine (n.d.)

The pig industry in Ukraine was experiencing negative trends. Among the challenges and threats to the industry were: low pig productivity and high costs, rising prices for feeds and feed additives, low feed quality, African swine fever problems in waste and wastewater management, outdated keeping technologies and methods of managing pork production, particularly among small-scale producers. Also, it was an insufficient provision of veterinary standards and biosecurity measures, when keeping pigs, low consumer solvency, considerable competition in the international pork market, logistical problems. Those factors urged agricultural producers to search for ways to increase the efficiency and profitability of pork production. Pork prices in Ukraine showed an unstable, but generally upward trend between January 2023 and March 2025 (Fig. 3). Average retail prices increased from UAH/kg 167.79 in January 2023 to over UAH/kg 190 in February 2025, with minor fluctuations due to seasonality and inflationary factors (Minfin, 2025).

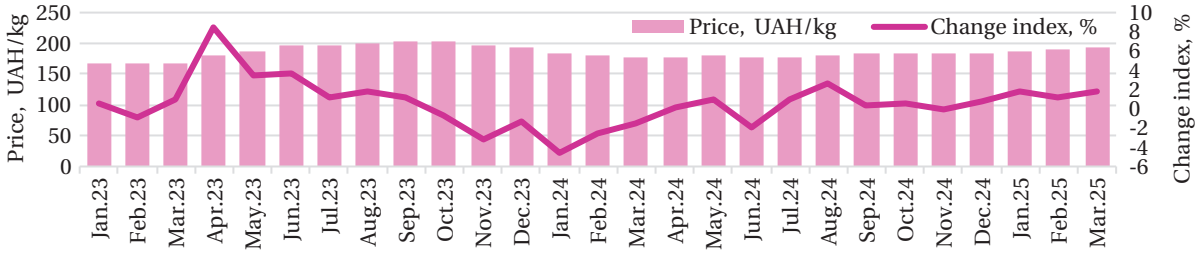

Figure 3. Pork prices in Ukraine monitoring, January 2023-March 2025
Source: based on Minfin (2025)

Purchase prices for live pigs fluctuated within UAH/kg 53-75, with a noticeable drop in mid-2024 due to power outages, mobilisation, and reduced consumer demand. At the same time, a significant increase in purchase prices was recorded by the beginning of 2025, which was associated with expectations of a reduction in livestock, a decrease in imports, and orientation towards the European price level. Overall, pricing in the pork market remained sensitive to external and internal challenges, and the cost of production was an important indicator of food stability. The implementation of the livestock development programme was impossible without the production of sufficient quantities of high-quality, nutritionally balanced feed. According to FAO (2018), one ton of such feed should ensure the production of 0.3 tons of pork. To achieve such indicators, it was necessary to develop the feed production system in large agricultural formations in accordance with their specialisation, using high-protein and energy feeds in pork and poultry meat production. In household feed production it was necessary: to make the most of natural meadows and pastures, to create collective lands of perennial and annual grasses, to cultivate grain and root crops; to use concentrated feeds only in the form of complete, balanced compound feeds and expand the use of premixes; to monitor the quality and safety of feeds, to bring those indicators to the EU requirements.

The main measures to fulfill the tasks set for ensuring the sufficient annual demand for high quality feed, were as follows: optimisation of the structure of sown areas of feed crops in accordance with the specialisation of the farm; development and introduction of the specialised feed crop rotations and concentration of feed production within a radius of 3-5 km from the place of keeping animals; increasing the specific share of high-yielding varieties of perennial leguminous and cereal grasses, annual legumes and soybeans, adapted to different conditions, resistant to pathogens, environmental stresses, having increased symbiotic activity. Also, important measures were an increasing productivity of feed crops through optimising their nutrition and maximising the use of organic fertilizers; using innovative technologies in the procurement and storage of feeds; strengthening control over the quality of feed raw materials; using modern technical means in feed production, which will contribute to labour productivity increase, optimisation of the work terms and improving the quality of feeds. Field feed production was an important component of pig feeding, as it provided access to natural and high-quality feed resources, reduces the cost of purchasing feed on the external market, allowed for the stability of feed supply, regardless of external market fluctuations or supply restrictions, producers can control the quality and safety of the field feed they grow, which allowed obtaining high-quality products. Using homegrown feeds contributed to sustainable production and optimisation of pig diets will ensure efficient use of resources and help to reduce the negative impact of feeding on the environment. In order to optimise pig feeding for sustainable production, 5 main directions should be identified (Fig. 4).

The implementation of those directions will contribute to the efficient use of resources, environmental protection and sustainable production of pig products. Ultimate feeding of animals was possible only if the diets contained all nutrients and biologically active substances in optimal quantities and ratios. The basis of pig diets was ensuring their nutritional needs at all stages of the life cycle. Diets can vary significantly depending on the production technology, age of the animals, their physiological needs and type of fattening (Monteiro *et al.*, 2025). Organisation of complete feeding of pigs was the basis for the effective use of feeds that contributed to optimal health, growth and productivity of pigs (Blavi *et al.*, 2021). According to M. Ibatullin (2017), the use of complete compound fed and, accordingly, a decrease in the share of feed per unit of production at the expense of reducing the cost of feed alone will allow reducing the cost of 1 ton of pig weight gain by UAH 1.3-1.5 thousand, in addition to the reduction in cost due to the increased weight gain on condition that total mixed ration was used. Analysis of the reasons, why Ukrainian agricultural producers spent more feed than necessary on the unit of production showed that

this negative phenomenon was caused by the unbalanced feeding of pigs. The main cost of the pig diet depended on the price of its filling, thus it was important to reasonably determine the feeding rations. It should be noted that in world practice, when compiling rations for pigs, three indicators of feed energy were used: digestible (DE), metabolisable (OE) and net (NE) one. It was possible to balance rations using any energy indicator, but the chosen model should be uniform. At the same time, in Ukrainian practice, agricultural enterprises producing pig products usually used the metabolisable energy indicator (Ibatullin, 2017). Optimisation of the pig feeding ration was an important component for the ensuring their optimal growth, development and health, including, in particular, scientifically substantiated balance of diets in energy, protein, essential amino acids, vitamins and minerals (Fig. 5).

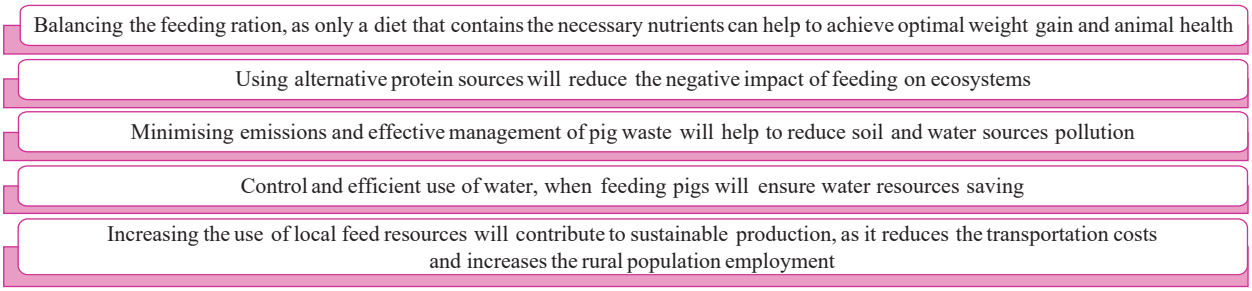

Figure 4. Main directions of optimising pig feeding for sustainable production
Source: developed by the authors

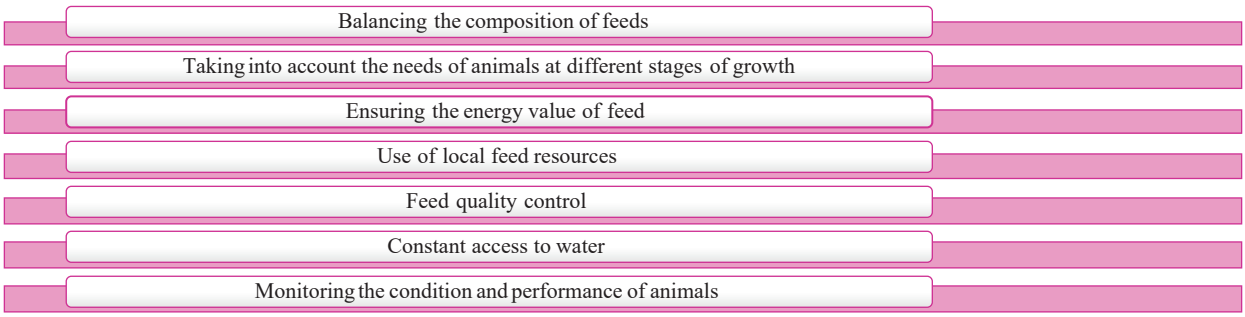

Figure 5. Principles of forming an optimised pig diet in conditions of high-performance production
Source: developed by the authors

The integrated use of those principles and effective use of feeds in pig farming helped to ensure maximal productivity, health and product quality. The implementation of modern research results and innovations in the field of pig feeding can contribute to the improvement of diets and increased productivity. Diet optimisation was a complex task that required consideration of many factors and analysis of the results. A properly balanced and adapted diet can help achieve maximum pig productivity and increase farm efficiency. Rational organisation of pig feeding at different stages of growth was a key factor in production efficiency. The "grower" group deserved special attention, which was characterised by the most intensive weight gain, active development of the skeleton and muscle tissue. It was at this stage that the need for scientifically based optimisation of the diet increases, which involved taking into account technological, economic and resource factors. The use of economic analysis modeling made it possible to form feed programmes with minimal cost without loss of animal productivity. Further detailing of the study of rations required the formalisation of the corresponding parameters in the mathematical model. In accordance with the defined groups of constraints, the designations of the sets *J1*, *J2*, *J3* were introduced, as well as the set of feed types *y* and homogeneous feeds *h*. Such formalisation allowed to isolate the economic content and structure of the model, which provided a scientific basis for optimising rations and forming effective management decisions. In accordance with the nutrient balance, the following restrictions were summarised:

$$\sum_{j\epsilon N} u_{ij} x_j \geq bi (i\epsilon J1). \quad (2)$$

According to the dry matter content (kg), it was:

$$\sum_{j\epsilon N} u_{ij} x_j \geq bi (i\epsilon J2). \quad (3)$$

According to the feed content in the diet (kg):

$$\sum_{j\epsilon N} u_{ij} x_j \geq bi (i\epsilon J3). \quad (4)$$

The objective function was:

$$f(x) = \sum_{j\epsilon N} c_j x_j \rightarrow min, \quad (5)$$

where c_j – the cost of a unit of feed of the *j*-th type.

Table 1 showed the feeding rates for pigs of the grower group.

Table 1. Feeding rates for the grower group pigs

Indicators	Values
Metabolisable energy, MJ	13
Crude protein, g	140
Digestible protein, g	109
Lysine	10
Methionine + cystine, g	6
Tryptophan, g	1.7
Crude fiber, g	60
Calcium, g	6
Phosphorus, g	7

Source: based on H. Bogdanov *et al.* (2012)

The model assumed a daily dry matter content in the diet of 1.2-1.5 kg and a mass of individual feed groups within the following limits: wheat grain – from 0.5 kg to 0.84 kg; barley grain – from 0.21 kg to 0.3 kg; triticale grain – from 0.21 kg to 0.3 kg; soybean meal – from 0.35 kg to 0.493 kg; Nutrimin premix – from 0.049 kg to 0.068 kg. Table 2 showed the nutritional value of feeds and their estimated market cost.

Table 2. Nutritional value of a unit of feed and its estimated cost

Indicators	Type of feed, kg				
	Wheat grain	Barley grain	Triticale grain	Soybean meal	Nutrimin premix
Physical quantity of feed, kg	0.5-0.84	0.21-0.3	0.21-0.3	0.35-0.493	0.049-0.068
Metabolisable energy, MJ	14.42	14.57	14.41	15.97	12.2
Crude protein, g	129.5	131.2	113	418	167
Digestible protein, g	95.8	78	85	307	145
Lysine, g	3.9	4.1	4.1	26.3	9.9
Methionine + cystine, g	4.1	3.6	3.6	11.3	3.27
Tryptophan, g	1.3	1.2	1.2	3.7	2.16
Crude fiber, g	21.9	36.9	49	54	5
Calcium, g	0.7	2	2	4.3	35
Phosphorus, g	4.3	3.9	3.9	6.9	5.24
Dry matter, g	850	850	850	900	984
Estimated cost, UAH per 1 kg	5.70	4.50	5.20	12.00	67.00

Source: developed by the author

The system of variables was determined in accordance with the problem statement: x_1 – wheat grain; x_2 – barley grain; x_3 – triticale grain; x_4 – soybean meal; x_5 – Grover pig premix. A system of restrictions has been developed for the first group, which reflected the nutritional requirements for the feeding ration in the amount not less than the norm (Table 3). The second group of restrictions showed the requirements for the dry matter content in the diet (Table 4). The third group of restrictions showed the permissible limits of feed content in the diet (Table 5).

Table 3. Equation of diet optimisation by nutrients (first group of restrictions)

Indicators	Equation
By the metabolisable energy, MJ	$14.42x_1+14.57x_2+14.41x_3+15.97x_4+12.2x_5\geq 13$
By crude protein content, g	$129.5x_1+131.2x_2+113x_3+418x_4+167x_5\geq 140$
By digestible protein content, g	$95.8x_1+78x_2+85x_3+307x_5+145x_5\geq 109$
By lysine content, g	$3.9x_1+4.1x_2+4.1x_3+26.3x_5+9.9x_5\geq 10$
By the content of "methionine + cystine", g	$4.1x_1+3.6x_2+3.6x_3+11.3x_5+3.27x_5\geq 6$
By tryptophan content, g	$1.3x_1+1.2x_2+1.2x_3+3.7x_5+2.16x_5\geq 1.7$
By the crude fiber content, g	$21.9x_1+36.9x_2+49x_3+54x_5+5x_5\geq 60$
By calcium content, g	$0.7x_1+2x_2+2x_3+4.3x_5+35x_5\geq 6$
By phosphorus content, g	$4.3x_1+3.9x_2+3.9x_3+6.9x_5+5.24x_5\geq 7$

Source: developed by the author

Table 4. Equation for the diet restrictions by the dry matter content (second group of restrictions)

Restriction	Equation
Not less than	$0.85x_1+0.85x_2+0.85x_3+0.9x_5+0.984x_5 \geq 1.2$
Not more than	$0.85x_1+0.85x_2+0.85x_3+0.9x_5+0.984x_5 \leq 1.5$

Source: developed by the author

Table 5. Permissible limits of feed content in the diet (third group of restrictions), kg

Indicators	Not less than	Not more than
Wheat grain	$x_1 \geq 0.5$	$x_1 \leq 0.84$
Barley grain	$x_2 \geq 0.21$	$x_2 \leq 0.3$
Triticale grain	$x_3 \geq 0.21$	$x_3 \leq 0.3$
Soybean meal	$x_4 \geq 0.35$	$x_4 \leq 0.49$
Nutrimin premix	$x_5 \geq 0.049$	$x_5 \leq 0.068$
Equation	$0.85x_1+0.85x_2+0.85x_3+0.9x_5+0.984x_5 \geq 1.2$	$0.85x_1+0.85x_2+0.85x_3+0.9x_5+0.984x_5 \leq 1.5$

Source: developed by the authors

Taking into consideration that the minimum cost of the ration was chosen as the optimality criterion, then the objective function, minimum cost of the ration (UAH) will be as follows:

$$F = 6.3x_1 + 4.2x_2 + 6.3x_3 + 9.5x_4 + 67x_5 \rightarrow min. \quad (6)$$

According to the optimal plan, the following feed should be included in the daily ration for the fattening pigs of the grower group: wheat grain – 0.5 kg; barley grain – 0.3 kg; triticale grain – 0.3 kg; soybean meal – 0.481 kg; Nutrimin premix – 0.068 kg (Table 6).

Table 6. Results of solving the economic and mathematical problem of optimising the daily ration for fattening pigs of the grower group

Limitation number	Variables	Types of feeds					Restriction		
	Name of limitations	Wheat grain	Barley grain	Triticale grain	Soybean meal	Nutrimin premix	Left side	Sign	Right side
		x_1	x_2	x_3	x_4	x_5			
	Variable values, kg	0.500	0.300	0.300	0.481	0.068			
	I. Nutrient balance								
1	Metabolic energy, MJ	14.42	14.57	14.41	15.97	12.2	24.421	≥	13
2	Crude protein, g	129.5	131.2	113	418	167	350.589	≥	140
3	Digestible protein, g	95.8	78	85	307	145	254.448	≥	109
4	Lysine, g	3.9	4.1	4.1	26.3	9.9	17.744	≥	10
5	Methionine + cystine, g	4.1	3.6	3.6	11.3	3.27	9.872	≥	6
6	Tryptophan, g	1.3	1.2	1.2	3.7	2.16	3.298	≥	1.7
7	Crude fibre, g	21.9	36.9	49	54	5	63.055	≥	60
8	Calcium, g	0.7	2	2	4.3	35	6.000	≥	6
9	Phosphorus, g	4.3	3.9	3.9	6.9	5.24	8.168	≥	7
	II. Dry matter content, kg								
10	min	0.850	0.850	0.850	0.900	0.984	1.435	≥	1.2
11	max	0.850	0.850	0.850	0.900	0.984	1.435	≤	1.5
	III. Feed content in the diet, kg								
12	Wheat grains min	1					0.500	≥	0.5
13	Wheat grains max	1					0.500	≤	0.84
14	Barley grains min		1				0.300	≥	0.21
15	Barley grains max		1				0.300	≤	0.3
16	Triticale grains min			1			0.300	≥	0.21
17	Triticale grains max			1			0.300	≤	0.3
18	Soybean cake min				1		0.481	≥	0.35
19	Soybean cake max				1		0.481	≤	0.49
20	Nutrimin min premix					1	0.068	≥	0.049
21	Nutrimin max premix					1	0.068	≤	0.068
	Minimum cost of the ration, UAH	**5.70**	**4.50**	**5.20**	**12.00**	**67.00**		**min**	**16.09**

Source: developed by the authors

According to the results of verification of the conditions fulfillment, the following was established: the 1st group of restrictions – the need for calcium is met at a minimum; the content of metabolisable energy, crude protein, digestible protein, lysine, methionine + cystine, tryptophan, crude fiber, phosphorus was above the minimum requirement; the 2nd group – the amount of dry matter exceeded the minimum required rate; the 3rd group – the amount of feed was within the recommended values. Objective function: with such composition of the diet, the minimum cost of the daily ration will be UAH 16.09, the cost per 1 kg of feed – UAH 9.76. The resulting diet was balanced in terms of nutrients and trace elements.

So, it was worth to noting that scientists B.M. Ali *et al.* (2018) proposed a stochastic bioeconomic model of pig farming to assess the impact of innovations in feeding on economic performance and environmental parameters of production. The results of their work confirmed the feasibility of using local by-products in pig rations, which ensured cost reduction, improved management decisions and increased profitability of the industry. Thus, an integrated approach to organising feeding opened up new opportunities for increasing the competitiveness of pig farming in Ukraine. An important confirmation was the results of the study by K.P. Pawłowski *et al.* (2025), which proved the effectiveness of economic analysis modeling in combining pig productivity with environmental responsibility of production. This approach created a methodological basis for further formalisation of parameters and optimisation of feeding programmes.

According to T. Prudyus *et al.* (2025), the rational use of feed additives activated natural and adaptive factors of the body's defenses in sows and piglets, allowing to increase the resistance and productivity of livestock. This created a scientific basis for economic and mathematical modeling of diets that took into account the biological needs of animals, the effective use of local feed resources and the principles of sustainable development of the industry, while ensuring a reduction in losses and an increase in production efficiency. The use of economic analysis models in this context made it possible not only to optimise diets according to the criteria of nutritional value and the cost of concentrated feeds, but also to integrate the results into a broader analysis of the economic efficiency of production. V. Orel & M. Korniietskyi (2021) believed that this approach allowed to assess the impact of feed costs on the cost and profitability of pig farming, taking into account the scale of production, investment, and logistics, which, in turn, contributed to the formation of scientifically sound strategies to increase the competitiveness of the industry.

The development and use of economic and mathematical models of operational forecasting provided the ability to determine the optimal parameters of rational pig feeding, outline the limits of investment risks, and select the most effective production options, taking into account the need and cost of concentrated feed, water, and energy sources (Pidtereba, 2022). The proposed economic analysis model allowed to form a balanced diet for pigs with the optimal inclusion of concentrated feeds, which ensured full satisfaction of the animals' needs for nutrients and minimised the cost of daily rations. The proposed approach demonstrated the effectiveness of integrating economic and biological parameters in the process of organising rational feeding, contributing to increasing productivity and economic feasibility of pig production.

Conclusions

In Ukraine, meat production was growing mainly due to poultry, while pork and beef volumes were decreasing, which indicated imbalances in the structure of the meat market. Live pork prices remain sensitive to external and internal factors, which emphasised the need to optimise production. The use of economic and mathematical approaches to organising rational pig feeding allowed for increased resource efficiency, reduced production costs, and improved stability and competitiveness of the industry. Modeling of the optimised diet for the pig fattening group showed that balanced feeding, taking into account the needs for protein, amino acids, energy, and macronutrients, allowed for a minimum daily ration cost of UAH 16.09, and the cost of 1 kg of feed was UAH 9.76. At the same time, all mandatory restrictions on the content of nutrients, dry matter, and the amount of feed in the diet were met. Such results confirmed the effectiveness of the economic and mathematical approach, focused on minimising costs while maintaining high productivity indicators.

The competitiveness of Ukrainian pig farming largely depends on effective rational feeding and the development of its own feed base. The use of cereals, legumes and oilseeds required adaptation to climate change and modern technologies for harvesting and storage. Economic analysis modeling showed that optimising the structure and cost of feed increases pig productivity, reduces costs and strengthens food security. The limitations of the study were related to the incompleteness of input data, the variability of biological and economic parameters, the dynamism of the market environment, methodological simplifications of models, insufficient digitalisation of production, and the influence of socio-economic factors that complicated the practical application of the results obtained. Further research should focus on price forecasting, the impact of climatic factors and the integration of alternative protein resources, which will contribute to the sustainable development of the industry and reduce its environmental impact.

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Conflict of interest

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Економіко-математичні підходи до організації раціональної годівлі свиней

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▸ **Анотація.** В умовах зростаючих вимог до продовольчої безпеки, ефективності виробництва та сталого розвитку сільського господарства, економіко-математичні підходи до організації раціональної годівлі свиней набули актуальності як інструмент для прийняття обґрунтованих управлінських рішень у галузі тваринництва. Метою статті була розробка та обґрунтування економіко-математичних моделей і методів оптимізації процесу годівлі свиней з урахуванням біологічних потреб тварин, ефективного використання кормових ресурсів та принципів сталого розвитку свинарської галузі. У дослідженні використано загальні та спеціальні методи економічного аналізу: монографічний, аналізу і синтезу, діалектичний, статистичний та абстрактно-логічний. У результатах дослідження висвітлено стан виробництва свинини у світі та Україні, зокрема, за 2015-2023 роки. Розглянуто моніторинг цін на свинину за період січень 2023-березень 2025 року. Окреслено основні напрямки розвитку кормовиробництва й оптимізації годівлі свиней для забезпечення сталого розвитку галузі в великотоварних та фермерських господарствах, господарствах населення. Визначено принципи формування оптимізованого раціону свиней в умовах високопродуктивного виробництва. Розраховано рівняння оптимізації раціону за поживними речовинами та вмістом сухої речовини. Визначено допустимі межі кормових інгредієнтів з урахуванням потреб свиней в обмінній енергії, сирому та перетравному протеїні, амінокислотах (лізин, метіонін + цистин, триптофан), сирій клітковині, сухій речовині, кальції та фосфорі. Оптимізація процесу годівлі дозволила мінімізувати вартість раціону. У дослідженні, для годівлі свиней групи гровер було рекомендовано використовувати: пшеницю – 0,5 кг, ячмінь – 0,3 кг, тритикале – 0,3 кг, соєву макуху – 0,481 кг, премікс Нутрімін – 0,068 кг. Було визначено, що вартість добового раціону становила 16,09 грн, або 9,76 грн за 1 кг, також раціон був збалансований за поживними речовинами та мікроелементами

▸ **Ключові слова:** свинарство; збалансований раціон; оптимізована годівля; модель економічного аналізу; концентровані корми