Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 3, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC EFFICIENCY OF PIG FATTENING USING FEED WITH LOW-DIGESTIBLE PROTEIN AND ADDING THE AMINO ACID SUPPLEMENT AMINOPRO

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Abstract

The study aimed to assess the economic efficiency in pig fattening using a new feed ration based on a low-digestible protein and adding the amino acid supplement AminoPro. For this purpose, the experiment included different levels and degrees of protein digestibility in diets supplemented with amino acids. In this way, it was possible to evaluate the fattening qualities of hybrid pigs. The experiment was conducted at the "Ryabushkivsky Bacon" pig complex in the Sumy region with F_1 hybrid pigs (VBxL sows x PIC-337 boars). Six groups of 20 pigs, divided by live weight and sex, were fed diets with varying protein digestibility. After a 30-day equalization period, five pigs with extreme weight gains were excluded, leaving 15 animals per group. Over 16 days, pigs were fed either quickly or poorly digestible protein diets with the AminoPro supplement. Dry compound feed was used throughout the experiment. Lightweight piglets on conventional diets with easily digestible protein achieved a final weight of 2.10 kg (1.56%) higher than those with AminoPro. Medium-weight pigs on conventional diets outperformed the experimental group by 2.60 kg (1.84%). Absolute weight gain in pigs fed AminoPro diets was 4.60 kg (6.03%) higher than those on conventional diets. Average daily gains increased by 53 g (6.04%) in medium-weight pigs consuming AminoPro. Feed conversion rations improved in lightweight pigs on conventional diets by 0.07 kg per gain, while medium-weight pigs on AminoPro consumed 0.27 kg less feed per kg of gain. Pigs fed AminoPro diets demonstrated higher fattening quality indices across all weight groups, with significant correlations between initial and final weights. The findings provide valuable insights for optimizing feeding strategies, improving growth performance, and reducing feed costs, contributing to greater profitability in pig production.

Key words*: pig fattening efficiency, low-digestible protein diets, AminoPro supplementation, growth performance*

INTRODUCTION

The composition of the diet is one of the most critical factors determining the production efficiency in pig farming. Optimal feeding contributes to the rapid growth of pigs and their health, improved meat quality, and reduced environmental impact [30, 33, 35]. Modern livestock farming emphasizes balanced diets that provide the necessary nutrients in optimal ratios [32]. This reduces feed costs and increases animal productivity, which is critically important in the growing demand for high-quality meat [10, 22]. The pigs' diet affects key indicators such as growth rate, feed conversion, health status, and reproductive capabilities. In addition, fine-tuning the composition of feeds using proteins, amino acids, vitamins, and minerals contributes to achieving environmental goals, such as reducing nitrogen emissions. Thus, competent ration formulation is the foundation of

sustainable and profitable pig farming [23, 24, 31].

Any modification to the feeding system influences the efficiency of pig rearing and fattening [21].

The protein content in a pig's diet is a crucial factor in determining growth and overall productivity [33]. As a primary source of essential amino acids, protein plays a vital role in muscle tissue development, metabolic regulation, and maintaining overall animal health [3, 13]. Maintaining an optimal protein level in the diet ensures maximum live weight gain, whereas both deficiencies and excesses can have adverse effects on productivity [15, 29]. A diet with a high protein content promotes active muscle mass gain, especially in young pigs in the initial stages of fattening. However, excessive amounts of protein can be inefficiently utilized by the body, leading to increased feed costs and nitrogen emissions into the environment. This can reduce production profitability and create environmental problems [14, 18]. Low protein levels in the diet lead to slower growth rates, lower feed conversion, and a weakened immune system. Pigs spend more energy on maintaining essential body functions than on growth, which negatively affects performance and increases the duration of fattening [9, 25].

Balanced protein diets provide optimal growth rates, support animal health, and reduce feed costs [7, 28]. Feed additives such as amino acids (lysine, methionine, threonine) allow for efficient protein absorption even when total crude protein levels are reduced. This ensures rapid muscle mass gain and reduces the negative impact on the environment [5, 15, 19].

The digestibility of protein in the diet is an important factor affecting the growth rate of pigs, as it determines what proportion of the protein consumed can be absorbed by the animal's body to ensure growth, maintain health, and regulate metabolic processes. High protein digestibility ensures more efficient use of nutrients, while low digestibility limits their availability and can lead to reduced gains [6, 16, 38].

Diets with easily digestible proteins contribute to maximum muscle growth, reduced feed consumption, and reduced nitrogen excretion. Amino acids derived from easily digestible protein are used for body protein synthesis, stimulating intensive growth of live weight. Because protein is digested more efficiently, less of it is wasted, which reduces the total amount of feed needed to achieve the desired results. Undigested protein is excreted from the body, which can lead to increased nitrogen emissions into the environment. High protein digestibility minimizes these losses [2, 8, 34, 34]. If protein in the diet has low digestibility, this can lead to reduced growth rates, increased feed consumption, and negative health effects. The pig body does not receive enough essential amino acids, which limits protein synthesis and slows down growth. To compensate for the deficit of available protein, larger feed volumes are required, which increases feeding costs. Undigested protein components can stimulate the development of pathogenic microflora in the intestine, which can cause gastrointestinal disorders. In particular, studies conducted [37] showed that pigs that received diets with low protein digestibility showed a decrease in average daily gains by 15–20% compared to those whose diets contained highly digestible protein. In addition, the feed conversion ratio increased since the animals needed more feed to achieve the desired results.

It was found [28] that low-digestible protein in diets led to accumulating undigested protein residues in the intestine. This stimulated the growth of pathogenic microflora, causing inflammatory processes and digestive disorders, which negatively affected the overall health of the animals and reduced growth rate.

Other studies [11] showed that diets with low protein digestibility increased nitrogen emissions by 20–30%. This created environmental problems and indicated a low efficiency of nutrient use in pig diets.

According report [26], young pigs with diets with low-digestible protein had significantly slower growth rates and delays in reaching slaughter weight. This is due to insufficient available amino acids for muscle tissue synthesis.

According to research [17], farmers who used cheaper protein components with low digestibility suffered losses due to the need to

increase the amount of feed by 10–15%. As a result, the cost of feeding became higher than when using high-quality protein components.

The digestibility of protein in the diet directly affects the growth rate of pigs. Diets with high digestibility provide efficient absorption of amino acids, contributing to maximum growth, reduced feed costs, and reduced environmental impact. On the contrary, low digestibility limits animal productivity and increases production costs [27].

To manage the growth rate of pigs with different initial weights, diets are adapted: for lighter animals, the protein and energy content is increased, and for heavier ones, it is reduced to avoid fat accumulation [1, 4]. In the case of a deficiency of natural protein, amino acid supplements are used to increase the digestibility of the diet, stimulate growth, and reduce feed costs [12].

The addition of limiting amino acids, such as lysine, methionine, threonine, and tryptophan, increases the efficiency of protein use, reduces the need for expensive protein feeds, and optimizes diets at different stages of pig development [17]. Amino acids help control the ratio of proteins and fats in animals and improve meat quality, making it leaner and more attractive to consumers [20].

Research into the use of indigestible protein with the addition of amino acids in pig fattening is relevant due to its significant impact on economic efficiency, livestock productivity, and environmental sustainability. Modern market conditions require reducing production costs, optimal use of resources, and minimizing environmental impact. At the same time, the increasing dependence on synthetic additives and the risk of ration imbalances highlight the need for accurate feed balancing and assessment of their impact on animal health and performance.

Research on this topic will help develop scientifically based recommendations for the efficient use of resources in pig farming, which is important for the industry's sustainable development in the face of modern economic and environmental challenges.

The study aims to determine the effectiveness of using indigestible protein by adding amino acids in fattening pigs to ensure optimal performance and reduce feed costs.

MATERIALS AND METHODS

To accomplish the study's objectives, an experiment was carried out to evaluate the fattening performance of F1 hybrid pigs, produced by crossing breed sows (GW×L) with terminal high-yielding PIC-337 boars. The research took place at the industrial pig farming complex LLC "RYABUSHKIVSKY BAKON" in Sumy region, Sumy district, under conditions involving varying levels and degrees of protein digestibility in the diet (Table 1).

The experiment accounted for different initial weights at the start of fattening and the pigs' sex. The animals were divided into six groups of 20 pigs each, with varying live weights during a 30-day equalization period in the enterprise's fattening facilities.

During the equalization period, all livestock received the same regular diet. Upon completion of the equalization period, five pigs with growth retardation and excessive gain were removed from each group.

During the next 16 days of fattening, the pigs were fed the same feed as during the equalization period to achieve a target weight of 110 kg.

On the 47th day of fattening, all animals were divided into groups based on live weight and kept in pens of 15 animals on a solid slatted floor at a rate of 1.04 m^2 per animal until the 87th day, after which they were sent for slaughter.

The first three groups of 15 animals each, I – with an average weight of 58 kg, II – with an average weight of 66 kg, III – with an average weight of 77 kg, were fed with diets containing easily digestible protein (Table 2).

Table 1. Research scheme

Groups	I	II	III	IV	V	VI
First equalization period						
Number of animals in the group, pig	20	20	20	20	20	20
Duration, days	30	30	30	30	30	30
Ration	Normal diet					
Second equalization period						
Number of animals in the group, pig	15	15	15	15	15	15
Duration, days	16	16	16	16	16	16
Ration	Normal diet					
Experimental period						
Number of animals in the group, pig	15	15	15	15	15	15
Duration, days	41	41	41	41	41	41
Ration	A ration with highly absorbable protein.	A ration with highly absorbable protein.	A ration with highly absorbable protein.	A feeding regimen containing low-digestibility protein and the AminoPro additive	A feeding regimen containing low-digestibility protein and the AminoPro additive	A feeding regimen containing low-digestibility protein and the AminoPro additive
Average weight at the beginning of fattening, kg	58	66	77	58	66	77

Source: own calculations.

Table 2. Composition of compound feeds for fattening pigs

Ingredient	Control Composition I	Experimental Composition II
Quantity of compound feed	1,000	1,000
Barley	246	214
Wheat	250	250
Corn	300	300
Bran	54	100
Soybean meal	130	115
Novacid	1	1
Chalk	7	7
Salt	4	4
Monocalcium phosphate	4	4
Trace elements	0.6	0.6
Vitamins	0.15	0.15
Kenzaim	0.278	0.278
Hadox	0.1	0.1
Betasorb	0.5	0.5
Lysine	2.25	2.25
Methionine	0.2	0.2
Aminoton		1
Licetin	0.2	0.2

Source: own calculations.

The remaining pigs were distributed according to their weight in the same way: Group IV – animals weighing 58 kg, Group V – pigs weighing 66 kg, VI – animals weighing 77 kg. The pigs of groups IV, V and VI, which were kept in a group pen of 15 animals, were fattened using feed with low protein digestibility, but with the addition of the feed additive AminoPro under other, identical housing conditions for the specified time (Table 3).

Table 3. Composition of the AminoPro feed vitamin supplement for fattening pigs

Ingredients	Units	Quantity
Vitamin A, min	MO	25,000.00
Vitamin D_3, min	MO	3,750.00
Vitamin E, min	mg	62.50

Source: own calculations.

The primary difference between the feeds lay in the proportion of indigestible and easily digestible protein, with the digestibility of the latter being adjusted through the influence of the AminoPro feed additive.

Throughout the experimental period, all groups were fed a dry compound feed produced on-site. It was formulated using BMVD as a base, supplemented with finely chopped formula

ingredients, and manually distributed twice daily via an automatic feeder (60×30×600 cm) with partitions, allowing fifteen pigs to feed simultaneously. After distribution, the feed was moistened in the drinker at a ratio of 1 part feed to 2 parts water (Photo 1). The amount of feed at each distribution corresponded to the fat content, age, daily requirements of the pigs and the specified intensity of average daily weight gain and allowed ad libitum consumption between each distribution.

It is important to mention that the daily feed mixing rate was continuously monitored by assessing the leftover feed in the feeders. As the pigs grew, the feed amount was gradually adjusted in response to their increasing consumption. The feed intake was recorded for each group by calculating the difference between the distributed feed mixture and the remaining feed after 24 hours.

Photo 1. General view of pig fattening sections
Source: Original.

Watering was carried out using nipple drinkers. Manure removal was done through underfloor baths with a drain frequency every 42 days. The microclimate of the premises was provided by supply-exhaust ventilation with air circulation through fans in window openings, drawing air into the interior of the premises in the warm season and extracting it in the cold.

The experiment results were biometrically processed using the MS Office Excel 2016 program. The reliability of differences between the mean values of the groups was determined using the Student t-test.

Any handling of experimental pigs met the requirements of EU legislation regarding their humane use during animal experiments. All procedures and manipulations during the experiment were aimed at avoiding the pain and suffering of the pigs.

The hypothesis suggests that incorporating feeds containing indigestible protein along with the AminoPro supplement in fattening pigs enhances both absolute and average daily weight gains compared to traditional feeds. This, in turn, leads to higher fattening productivity and improves the overall efficiency of pig farming operations.

RESULTS AND DISCUSSIONS

The most significant statistical differences were found in average daily gain, relative gain, age at reaching 100 kg, and feed consumption for groups with an average initial weight at the start of fattening (Table 4). Regarding the final weight at the end of fattening, piglets with medium initial weight consuming hard-to-digest protein with an amino acid supplement showed a 4.1 kg (2.89%) increase ($p<0.05$) compared to those consuming feed with easily digestible protein. Additionally, both light-weight gilts and medium-weight piglets exhibited a higher average daily gain: light-weight gilts gained 16 g (1.81%) more ($p<0.05$), while medium-weight piglets and gilts gained 63 g (7.11%) ($p<0.05$) and 56 g (6.34%) ($p<0.05$) more, respectively. Piglets with average initial weight whose feed contained the AminPro supplement showed a 4.0% ($p<0.05$) higher relative gain compared to piglets with normal feed.

Both the lightweight gilts and the lightweight boars fattened on the experimental diet reached a weight of 100 kg faster than their peers consuming feed with easily digestible protein, by 12.0 days (8.96 %) ($p<0.05$) and 11.1 days (8.34 %) ($p<0.05$) respectively.

The analysis of feed consumption per kilogram of gain revealed higher values for this indicator in piglets with average initial weight, which were fed a diet with easily digestible protein, compared to those that received an amino acid supplement, with a difference of 0.27 kg (5.64%). Additionally, medium-weight pigs fed a standard diet had a 0.25 kg (5.24%) higher feed conversion ratio than those on the experimental diet. Other factors, such as initial and final weight, absolute gain, and feed consumption in groups of pigs with low and high initial weights at the start of fattening, did not show significant statistical differences, but only a trend toward differences in fattening performance.

Table 4. Fattening performance of pigs at different initial weights and different diets during fattening

Groups	I	II	III	IV	V	VI
	Weight at the beginning of fattening. Kg					
Boars	58.1±0.04[a]	65.9±0.10[a]	72.2±1.01[a]	58.0±0.51[a]	64.2±0.43[a]	69.9±0.35[a]
Gilts	58.2±0.07[a]	65.1±0.22[a]	71.1±1.10[a]	57.3±0.56[a]	63.3±0.38[a]	69.4±0.69[a]
	Weight at the end of fattening. Kg					
Boars	135.0±0.67[a]	142.1±0.52[a]	148.5±2.13[a]	133.4±1.81[a]	146.2±1.85[b]	146.1±1.73[a]
Gilts	134.8±0.91[a]	141.3±0.75[a]	146.8±1.91[a]	132.6±2.14[a]	143.8±2.01[a]	145.3±1.70[a]
	Absolute gain. G					
Boars	77.1±0.47[a]	77.1±0.61[a]	77.1±1.10[a]	76.2±1.76[a]	81.9±1.36[a]	76.3±2.01[a]
Gilts	76.5±0.91[a]	75.9±0.33[a]	75.7±2.94[a]	75.2±1.90[a]	80.5±1.72[a]	76.0±2.26[a]
	Average daily gain. G					
Boars	885±0.01[a]	886±0.01[a]	883±0.02[a]	885±0.01[a]	949±0.02[b]	881.0±0.03[a]
Gilts	884±0.01[a]	883±0.01[a]	879±0.03[a]	868±0.02[b]	939±0.02[b]	871.0±0.02[a]
	Relative growth. %					
Boars	79.9±0.37[a]	73.8±0.29[a]	68.9±1.43[a]	79.8±1.18[a]	78.8±0.83[b]	71.0±1.63[a]
Gilts	79.2±0.56[a]	73.7±0.32[a]	69.4±1.41[a]	79.0±1.17[a]	77.7±0.85[b]	70.6±1.74[a]
	Number of days in fattening					
Boars	87.0	87.0	87.0	87.0	87.0	87.0
Gilts	87.0	87.0	87.0	87.0	87.0	87.0
	Age of reaching 100 kg weight. Days					
Boars	133.9±0.54[a]	126.9±0.63[a]	121.9±1.65[a]	121.9±2.08[a]	124.0±1.60[a]	125.2±1.47[a]
Gilts	133.1±0.89[a]	127.3±0.68[a]	122.8±2.36[a]	122.0±2.21[b]	125.2±1.76[a]	122.9±1.41[a]
	Feed consumption per 1 kg of gain. Kg					
Boars	4.77	4.78	4.79	4.84	4.51	4.79
Gilts	4.72	4.77	4.75	4.80	4.52	4.78

Notes: Different lowercase letters (a, b) indicate statistical difference between fattening parameters at the $p<0.05$ level or higher.
Source: own calculations.

A two-factor analysis of variance was conducted to evaluate the impact of initial weight and diet on the fattening characteristics of pigs (Fig. 1). The analysis revealed that only relative gain was significantly affected by these factors, with the initial weight contributing 78.5% and the diet contributing 3.6%. However, there was no such dependence observed for absolute and daily gains. The age at which pigs reached a live weight of 100 kg was influenced by the initial live weight by 83.1%, while the final weight was influenced by the initial weight by 82.6%, with no effect from the other factors.

Comparing the performance of the groups of lightweight pigs fed the easily digestible protein diet and low-starting pigs fed the poorly digestible protein diet supplemented with AminoPro, the initial weight in both groups was the same at 58.0 kg.

The final weight of the pigs in the first group was 1.6 kg (1.2%) higher (135.0 kg vs. 133.4 kilograms). The cost of fattening pigs in the fourth group was 2.2 EUR (2.4%) higher, and the feed cost was 1.6 EUR (2.4%). The income of the lightweight pigs was 2.9 EUR (1.2%) higher, and the profit was 5.1 EUR (3.5%). The profitability in the first group was 1.4% higher than in the fourth (62.4% and 61.0%) (Table 5).

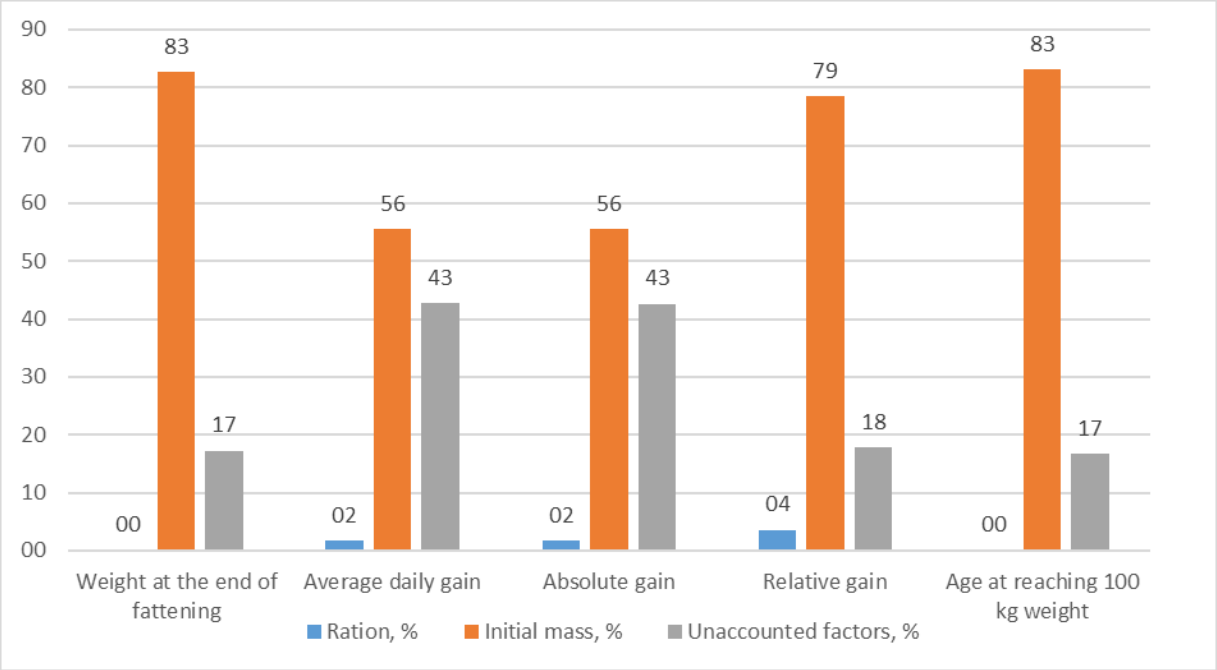

Fig. 1. The influence of weight at the beginning of fattening and diet on the fattening qualities of pigs
Source: own calculations.

Table 5. Economic efficiency of fattening pigs when using easily digestible and difficult-to-digest protein in the feed

Indicator	I	II	III	IV	V	VI
	A ration with highly absorbable protein			A feeding regimen containing low-digestibility protein and the AminoPro additive		
Initial live weight, kg	58.0	66.0	77.0	58.0	66.0	77.0
Live weight price, EUR/kg	1.8	1.8	1.8	1.8	1.8	1.8
Cost of fattening 1 pig in the experiment, EUR	90.7	95.5	103.8	92.9	97.5	104.3
Including the cost of feed spent on fattening 1 pig, EUR	67.2	70.8	76.9	68.8	72.2	77.2
Percentage of feed spent on fattening in the total cost of 1 pig, %	74.1	74.1	74.1	74.1	74.1	74.1
Average live weight at the end of fattening, kg	135.0	142.1	148.5	133.4	146.2	146.1
Income from the sale of one piglet (excluding VAT), EUR	241.1	253.8	265.2	238.2	261.1	260.9
Profit from fattening 1 pig, EUR	150.4	158.2	161.4	145.3	163.6	156.6
Profitability of fattening 1 pig, %	62.4	62.3	60.9	61.0	62.7	60.0

Source: own calculations.

The average-weight pigs fed the easily digestible protein, and their counterparts fed the indigestible protein and AminoPro supplement had the same initial weight of 66.0 kg. However, the average weight of pigs on the experimental feed had a final weight that was 4.1 kg (2.9%) higher (146.2 kg vs. 142.1 kg). The cost of fattening in group 5 was 2.0 EUR (2.1%) higher, and the feed cost was 1.4 EUR (2.0%). The income in the fifth group was 7.3 EUR (2.9%) higher than in the second, and the profit was 5.4 EUR (3.4%). The profitability in the fifth group was 0.4% higher than in the second (62.7% vs. 62.3%).

A comparison of heavy pigs fed conventional feed and counterparts fed the indigestible protein with AminoPro supplement showed that their initial weight was the same - 77.0 kg. However, the final weight of pigs in the third group was 2.4 kg (1.6%) higher (148.5 kg vs. 146.1 kg). The cost of fattening in the sixth group was 0.5 EUR (0.5%) higher, and the feed cost was 0.3 EUR (0.4%) higher. The income in the third group exceeded the similar indicator in the sixth by 4.3 EUR (1.6%), and the profit by 4.8 EUR (3.1%). The profitability of fattening in the third group was 0.9% higher (60.9% vs. 60.0%).

Thus, medium-weight pigs receiving the experimental feed recorded the highest profitability and cost-effectiveness indicators.

In general, our results confirm the importance of a rational approach to the design of pig diets, considering both initial live weight and the use of protein supplements.

As reports [1] mention, the diet should consider the animals' initial weight to ensure optimal growth and avoid excessive fat accumulation. In our studies, the average daily gain was significantly higher in pigs of the medium-weight group fed hard-to-reach proteins with amino acid supplements. In particular, the gain in these animals was 63 g (7.11 %) higher in boars and 56 g (6.34 %) higher in gilts, which is consistent with the statement that optimizing the protein content in the diet promotes intensive growth of muscle mass [17].

According to [37], low available protein without amino acids can reduce animal performance and prolong the fattening period. According to our data, using experimental feed shortened the time to reach 100 kg by 12.0 days (8.96%) in gilts and 11.1 days (8.34%) in boars in the lightweight group. These results show that adding amino acids makes it possible to compensate for the inadequacies of hard-to-access protein and increase its digestibility and performance.

Similar to the widely reported data [7] that a balanced diet helps to reduce feed costs, we found confirmation of the statement that feed costs per 1 kg gain were 0.27 kg (5.64 %) lower in medium-weight pigs fed diets containing amino acids than in pigs fed easily digestible protein. This our finding indicates the economic feasibility of using protein supplements.

In our study, the relative gain was 4.0 higher in medium-weight boars fed a hard-to-access protein with amino acids, confirming the role of amino acids in stimulating growth, similar to the results of [28], which indicates that the balance of amino acids and proteins ensures an effective increase in muscle mass.

Therefore, most of our results align with the literature sources and confirm the effectiveness of using hard-to-access proteins with amino acid supplements to increase pig performance, especially in pigs with an average initial weight.

CONCLUSIONS

The inclusion of hard-to-digest proteins along with the amino acid supplement AminoPro enhances pig productivity by increasing average daily gain, shortening the time to reach a live weight of 100 kg, and reducing feed costs per unit of gain.

At the start of fattening, piglets in the average weight group that received these proteins with amino acids demonstrated significantly higher weight gains, reached slaughter weight more quickly, and required less feed per kilogram of gain. The use of cheaper protein components in combination with amino acid supplements reduces feeding costs without compromising animal productivity.

The initial live weight of pigs plays a key role in determining feeding efficiency and weight gain. Animals with an average weight at the beginning of fattening showed the best results in terms of productive indicators.

The highest profitability and cost-effectiveness rates were recorded in medium-weight pigs fed a feed of indigestible protein supplemented with AminoPro. However, this feed did not provide a positive economic effect on financial indicators in light-weight and heavy-weight pigs.

REFERENCES

[1]Ahlborn, N. G., Montoya, C. A., Roy, D., Roy, N. C., Stroebinger, N., Ye, A., Samuelsson, L. M., Moughan, P. J., McNabb, W. C., 2023, Differences in small

intestinal apparent amino acid digestibility of raw bovine, caprine, and ovine milk are explained by gastric amino acid retention in piglets as an infant model. Frontiers in Nutrition, Vol. 10: 1226638. https://doi.org/10.3389/fnut.2023.1226638

[2]Bikker, P., Verstegen, M. W., Bosch, M. W., 1994, Amino acid composition of growing pigs is affected by protein and energy intake. The Journal of Nutrition, Vol. 124(10): 1961–1969. https://doi.org/10.1093/jn/124.10.1961

[3]Bilyavtseva, V. V., 2017, Productivity of young pigs fed protein-vitamin-mineral supplement "Enervik" [Productivity of young pigs fed protein-vitamin-mineral supplement "Enervik"]. Dissertation for the Doctor of Philosophy degree. Vinnytsia, Ukraine. [in Ukrainian]. http://science.btsau.edu.ua/sites/default/files/specradi/dis_biluavceva.pdf Accessed on 27.01.2025.

[4]Duarte, M. E., Parnsen, W., Zhang, S., 2024, Low crude protein formulation with supplemental amino acids for its impacts on intestinal health and growth performance of growing-finishing pigs. Journal of Animal Science and Biotechnology, Vol. 15: 55. https://doi.org/10.1186/s40104-024-01015-6

[5]Esteves, L. A. C., Monteiro, A. N. T. R., Sitanaka, N. Y., Oliveira, P. C., Castilha, L. D., Paula, V. R. C., Pozza, P. C., 2021, The reduction of crude protein with the supplementation of amino acids in the diet reduces the environmental impact of growing pigs production evaluated through life cycle assessment. Sustainability, Vol. 13(9): 4815. https://doi.org/10.3390/su13094815

[6]Fang, L. H., Jin, Y. H., Do, S. H., Hong, J. S., Kim, B. O., Han, T. H., Kim, Y. Y., 2019, Effects of dietary energy and crude protein levels on growth performance, blood profiles, and nutrient digestibility in weaning pigs. Asian-Australasian Journal of Animal Sciences, Vol. 32(4): 556–563. https://doi.org/10.5713/ajas.18.0294

[7]FAO, 2012, Impact of animal nutrition on animal welfare – Expert Consultation 26−30 September 2011 – FAO Headquarters, Rome, Italy. Animal Production and Health Report. No. 1. Rome. https://www.fao.org/4/i3148e/i3148e00.pdf Accessed on 27.01.2025

[8]Fuller, M., 2012, Determination of protein and amino acid digestibility in foods including implications of gut microbial amino acid synthesis. British Journal of Nutrition, Vol. 108(S2): 238–246. https://doi.org/10.1017/S0007114512002279

[9]Han, Y. G., Lee, G. I., Do, S. H., Jang, J. C., Kim, Y. Y., 2023, The effect of reduced crude protein on growth performance, nutrient digestibility, and meat quality in weaning to finishing pigs. Animals, Vol. 13(12): 1938. https://doi.org/10.3390/ani13121938

[10]Hryshchenko, N. P., 2014, Udoskonalennia tekhnolohichnykh pryiomiv vidhodivli molodniaku svynei [Improvement of technological methods of fattening young pigs]. Abstract of Ph.D. dissertation. Kyiv, Ukraine. [in Ukrainian] http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=S&I21DBN=EC&P21DBN=EC&S21FMT=JwU_B&S21ALL=%28%3C.%3EU%3D%D0%9F65-44%3C.%3E%29&Z21ID=&S21SRW=GOD&S21SRD=DOWN&S21STN=1&S21REF=10&S21CNR=20 Accessed on 27.01.2025

[11]Hiuson-Khiuz, A., 2024, Rozrobka pidkhodu do hidrolizu bilkiv dlia pidvyshchennia pozhyvnykh vlastyvostei svizhopryhotovanoho miasa ta ryby [Development of an approach to protein hydrolysis for improving the nutritional properties of fresh meat and fish]. Pet Food Partners. [in Ukrainian] https://ga-petfoodpartners.co.uk/uk/%D0%B3%D1%96%D0%B4%D1%80%D0%BE%D0%BB%D1%96%D0%B7-%D0%B1%D1%96%D0%BB%D0%BA%D0%B0-HDP/?utm_source=chatgpt.com Accessed on 27.01.2025.

[12]Hu, N., Shen, Z., Pan, L., Qin, G., Zhao, Y., Bao, N., 2022, Effects of protein content and the inclusion of protein sources with different amino acid release dynamics on the nitrogen utilization of weaned piglets. Animal Bioscience, Vol. 35(2): 260–271. https://doi.org/10.5713/ab.21.0142

[13]Ibagon, J. A., Lee, S. A., Stein, H. H., 2021, Sunflower expellers have greater ileal digestibility of amino acids than sunflower meal, but there are only minor variations among different sources of sunflower meal when fed to growing pigs. Journal of Animal Science, Vol. 99(8): skab198. https://doi.org/10.1093/jas/skab198

[14]Johannsen, J. C., Nørgaard, J. V., Theil, P. K., Andersen, H. M. L., Kongsted, A. G., 2023, Effects of a high protein starter diet with fermented soybean cake on growth performance of organic pigs weaned outdoor. Livestock Science, Vol. 267: 105141. https://doi.org/10.1016/j.livsci.2022.105141

[15]Kim, S. W., Less, J. F., Wang, L., Yan, T., Kiron, V., Kaushik, S. J., Lei, X. G., 2019, Meeting global feed protein demand: Challenge, opportunity, and strategy. Annual Review of Animal Biosciences, Vol. 7(1): 221–243. https://doi.org/10.1146/annurev-animal-030117-014838

[16]Kim, H., Shin, H., Kim, Y. Y., 2023, Effects of different levels of dietary crude protein on growth performance, blood profiles, diarrhea incidence, nutrient digestibility, and odor emission in weaning pigs. Animal Bioscience, Vol. 36(8): 1228–1240. https://doi.org/10.5713/ab.22.0440

[17]Langyan, S., Yadava, P., Khan, F. N., Dar, Z. A., Singh, R., Kumar, A., 2022, Sustaining protein nutrition through plant-based foods. Frontiers in Nutrition, Vol. 8: 772573. https://doi.org/10.3389/fnut.2021.772573

[18]Lestingi, A., 2024, Alternative and sustainable protein sources in pig diet: A review. Animals, Vol. 14(2): 310. https://doi.org/10.3390/ani14020310

[19]Liao, S. F., Wang, T., Regmi, N., 2015, Lysine nutrition in swine and the related monogastric animals: Muscle protein biosynthesis and beyond. SpringerPlus, Vol. 4: 147. https://doi.org/10.1186/s40064-015-0927-5

[20]Ma, X., Yu, M., Liu, Z., Deng, D., Cui, Y., Tian, Z., Wang, G., 2020, Effect of amino acids and their derivatives on meat quality of finishing pigs. Journal of Food Science and Technology, Vol. 57(2): 404–412.

[21]Moisei, I., Povod, M., Mykhalko, O., Povoznikov, M., Gutyj, B., Ievstafiieva, Y., Buchkovska, V., 2024, Effectiveness of rearing and fattening of low-weight piglets due to changes in their feeding systems. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 24(3), 577-588.
[22]Mykhalko, O. G. 2021a, Vidhodivelni yakosti svynei irlandskoho pokhodzhennia za riznoho typu hodivli [Feeding qualities of pigs of Irish origin under different types of feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo", Vol. 3: 51–56. [in Ukrainian]. https://doi.org/10.32845/bsnau.lvst.2020.3.9
[23]Mykhalko, O. G. 2021b, Zalezhnist vidhodivelnykh yakostei svynei danskoho pokhodzhennia vid typu hodivli [Dependence of the feeding qualities of pigs of Danish origin on the type of feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo", Vol. 4(47): 99–108. [in Ukrainian]. https://doi.org/10.32845/bsnau.lvst.2021.4.17
[24]Patience, J. F., Rossoni-Serão, M. C., Gutiérrez, N. A. 2015, A review of feed efficiency in swine: Biology and application. Journal of Animal Science and Biotechnology, Vol. 6: 33. https://doi.org/10.1186/s40104-015-0031-2
[25]Olson, S., 2020, Low-protein diets help slow finishing pig growth. Feedstuffs. https://www.feedstuffs.com/nutrition-and-health/low-protein-diets-help-slow-finishing-pig-growth, Accessed on 27.01.2025
[26]Peinado, J., Serrano, M. P., Nieto, M., Medel, P., Mateos, G. G., 2012, The effects of gender and castration of females on performance and carcass and meat quality of heavy pigs destined to the dry-cured industry. Meat Science, Vol. 90(3): 715–720. https://doi.org/10.1016/j.meatsci.2011.11.001
[27]Podkhalyuzina, O. M., Bomko, V. S., Kuzmenko, O. A., 2020, Peretravnist kormu ta produktyvnist molodniaku svynei na vidhodivli za vykorystannia zmishanolihandnoho kompleksu Kuprumu [Feed digestibility and productivity of young pigs for fattening using a mixed-ligand complex of Copper]. Tekhnolohiia vyrobnytstva i pererobky produktsii tvarynnytstva: zbirnyk naukovykh prats [Technology of Production and Processing of Livestock Products: Collection of Scientific Papers], Vol. 1(156): 118–124. [in Ukrainian]. https://doi.org/10.33245/2310-9270-2020-157-1-118-124
[28]Pomar, C., Andretta, I., Remus, A., 2021, Feeding strategies to reduce nutrient losses and improve the sustainability of growing pigs. Frontiers in Veterinary Science, Vol. 8: 742220. https://doi.org/10.3389/fvets.2021.742220
[29]Povod, M. G., Mikhalko, O. G., Shpetny, M. B., Opara, V. O., 2021, Produktyvni yakosti vidhodivelnoho molodniaku svynei za riznoho rivnia proteinu v ratsioni [Productive qualities of fattening young pigs at different levels of protein in the diet]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia: Tvarynnytstvo [Bulletin of the Sumy National Agrarian University. Series "Livestock"], Vol. 3(46): 79–84. [in Ukrainian]. https://doi.org/10.32845/bsnau.lvst.2021.3.10
[30]Povod, M. G., Tishchenko, O., Mykhalko, O. G., Verbelchuk, T. V., Verbelchuk, S. P., Sherbyna, O. V., Kalynychenko, H. I., 2022, Intensyvnist rostu ta vidhodivelni yakosti svynei pry zmini sposobiv hodivli v period vidtvorennia ta vidhodivli [Growth intensity and fattening qualities of pigs during changes in feeding types during reproduction and fattening]. Naukovyi visnyk Lvivskoho natsionalnoho universytetu veterynarnoi medytsyny ta biotekhnolohii. Seriia: Ahrarni nauky [Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies. Series: Agricultural Sciences], Vol. 24(96): 50–60. [in Ukrainian]. https://doi.org/10.32718/nvlvet-a9607
[30]Povod, M. G., Kondratiuk, V. M., Lykhach, V. Ya., Mykhalko, O. G., Izhboldina, O. O., Povoznikov, M. G., Gutyi, B. V., 2022, Efektyvnist vykorystannia innovatsiinykh proteinovykh komponentiv v hodivli svynei [Effectiveness of using innovative protein components in pig feeding]. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu. Seriia "Tvarynnytstvo" [Bulletin of the Sumy National Agrarian University. "Livestock" Series], Vol. 2(49): 24–36. [in Ukrainian]. https://doi.org/10.32845/bsnau.lvst.2022.2.5
[31]Povod, M. G., Tishchenko, O. S., Mykhalko, O. G., Verbelchuk, T. V., Verbelchuk, S. P., Shcherbyna, O. V., Kalinichenko, H. I., 2022, Intensyvnist rostu ta vidhodivelni yakosti svynei za zminy typiv hodivli pid chas doroshchuvannia ta vidhodivli [Intensity of growth and fattening qualities of pigs due to changes in types of feeding during rearing and fattening]. Naukovyi visnyk LNUVMB imeni S.Z. Gzhytskoho. Seriia: Silskohospodarski nauky [Scientific Bulletin of the LNUVMB named after S.Z. Gzhitskyi. Series: Agricultural Sciences], Vol. 24(96): 50–60. [in Ukrainian]. https://doi.org/10.32718/nvlvet-a9607
[33]Povod, M., Mykhalko, O., Povoznikov, M., Gutyj, B., Koberniuk, V., Shuplyk, V., Ievstafiieva, Y., Buchkovska, V., 2022, Efficiency of using high-protein sunflower meal instead of soybean meal in feeding of growing piglets. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 22(4), 595-602.
[34]Spiehs, M. J., 2005, Nutritional and feeding strategies to minimize nutrient losses in livestock manure. The Pig Site. https://www.thepigsite.com/articles/nutritional-and-feeding-strategies-to-minimize-nutrient-losses-in-livestock-manure, Accessed on 27.01.2025.
[35]Tishchenko, O., Povod, M., Gutyj, B., Verbelchuk, T., Verbelchuk, S., Koberniuk, V., Maistrenko, O., 2023, Efektyvnist riznykh system ridkoi hodivli porosiat na doroshchuvanni v umovakh promyslovoi tekhnolohii [Effectiveness of different systems of liquid feeding of piglets in the conditions of industrial technology]. Naukovyi visnyk LNU veterynarnoi medytsyny ta biotekhnolohii. Seriia: Silskohospodarski nauky [Scientific Bulletin of LNU of Veterinary Medicine and

Biotechnology. Series: Agricultural Sciences], Vol. 25(98): 185–193. [in Ukrainian]. https://doi.org/10.32718/nvlvet-a9830

[34]van Milgen, J., Dourmad, J. Y., 2015, Concept and application of ideal protein for pigs. Journal of Animal Science and Biotechnology, Vol. 6: 15. https://doi.org/10.1186/s40104-015-0016-1

[35]Voitsitskyi, O., Novgorodska, N., 2023, Enzymes and their application in the diets of pigs. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Agricultural Sciences, Vol. 25(98): 77–82. https://doi.org/10.32718/nvlvet-a9813

[36]Zhao, Y., Tian, G., Chen, D., Zheng, P., Yu, J., He, J., Mao, X., Hung, Z., Luo, Y., Yu, B., 2019, Effect of different dietary protein levels and amino acids supplementation patterns on growth performance, carcass characteristics, and nitrogen excretion in growing-finishing pigs. Journal of Animal Science and Biotechnology, Vol. 10: 75. https://doi.org/10.1186/s40104-019-0381-2

[37]Zoric, M., Johansson, S. E., Wallgren, P., 2015, Behaviour of fattening pigs fed with liquid feed and dry feed. Porcine Health Management, Vol. 1: 14. https://doi.org/10.1186/s40813-015-0009-7