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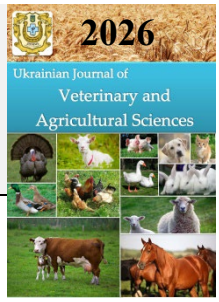

Effect of the probiotic feed additive Natupro on the productive performance and economic efficiency of piglets during the nursery period

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Abstract

This study presents the results of a comprehensive evaluation of the effects of the probiotic feed additive Natupro on the growth performance and economic efficiency of nursery piglets. The experiment was conducted under commercial swine production conditions using hybrid piglets obtained from Landrace × Large White sows inseminated with PIC 337 terminal-line boars of British origin. Experimental groups were formed according to the principle of analogs, taking into account the age and initial body weight of the animals. In addition to the basal diet, piglets in the experimental group received 0.5 % of the probiotic feed additive Natupro. The results demonstrated that probiotic supplementation enhanced piglet growth performance throughout the nursery period. Piglets receiving 0.5 % Natupro exhibited average daily gains that exceeded those of the control group by 3.6–6.6 %, resulting in a 4.2 % increase in total weight gain and a 3.4 % higher final body weight. The improved growth performance was accompanied by a slight increase in survival rate and stabilization of the physiological condition of the animals, particularly during the critical post-weaning period. The increase in productivity was associated with greater feed intake, while feed conversion efficiency improved slightly (approximately 0.6 %), indicating more efficient utilization of dietary nutrients. At the same time, inclusion of the probiotic additive increased total feeding costs by 14.2 %. It raised the feed cost per kilogram of weight gain by 9.6 %, reflecting both higher feed consumption and the additional cost of the probiotic preparation. Despite higher feed costs, the higher growth rate and increased final body weight reduced the production cost per kilogram of live weight by 4.3 %. Consequently, the market value of the growing pigs increased by 3.4 %, resulting in a 5.2 % increase in profit and a 2.7 % improvement in production profitability. In conclusion, supplementing nursery piglet diets with 0.5 % Natupro is an effective nutritional strategy to improve growth performance during the nursery period. The economic benefits of its application are primarily attributable to enhanced animal productivity despite increased feeding costs, indicating the potential for further optimization of its use under commercial swine production conditions.

Keywords: nursery piglets; probiotic; Natupro; growth performance; average daily gain; feed intake; feed conversion ratio; economic efficiency; production cost; profitability.

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1. Introduction

The nursery period is recognized as one of the most critical stages in pig production, as it largely determines pigs' growth performance, viability, and subsequent productive potential (Lykhach et al., 2023; Mezhenskyi et al., 2025). According to Sokolov (2018) and Wensley et al. (2021), weaning in modern swine production is performed at an early age. It represents a critical management practice associated with profound physiological and behavioral changes. In contrast, under natural conditions, weaning occurs gradually, allowing piglets to adapt progressively to changes in diet and environmental conditions.

Under commercial production systems, early weaning exposes piglets to multiple stressors, including abrupt dietary changes, relocation to a new environment, and disruption of social hierarchy, all of which adversely affect feed intake, immune function, and intestinal health (Zheng et al., 2021; Fabà et al., 2025). Reduced feed intake during the first days after weaning contributes to intestinal villus atrophy,

impaired digestive enzyme activity, and an increased incidence of post-weaning diarrhea, ultimately compromising growth performance (Boudry et al., 2004; Campbell et al., 2013; Holman et al., 2021; Tang et al., 2024).

Initial body weight is another important determinant of nursery performance. Studies by Berkeveld et al. (2007), Collins et al. (2017), and Moisei et al. (2025) have demonstrated that piglets with lower body weight exhibit reduced growth rates and increased mortality. The management strategy during the suckling period is also of considerable importance. According to Colson et al. (2006), Povod et al. (2019), Ming et al. (2021), and Moisei et al. (2025), longer lactation periods and the provision of creep feed improve adaptation to the post-weaning period and contribute to better subsequent growth performance.

Housing conditions, particularly microclimatic parameters, represent another key factor affecting nursery efficiency. Studies by Voloshchuk and Herasymchuk (2017), Zhyzhka and Povod (2019), and Aliyev and Belous (2020) demonstrated that ventilation systems significantly influence air temperature, relative humidity, and gas composition in nursery facilities, thereby affecting piglet growth and survival. Furthermore, investigations by Herasymchuk et al. (2025), Mykhalko et al. (2024), and Povod et al. (2017) confirmed that optimizing ventilation systems improves productivity while reducing disease incidence.

As reported by Yaropud and Aliiev (2021) and Ladyka et al. (2020), optimal microclimatic conditions, including temperature, relative humidity, and air velocity, are essential for young pigs because of their high sensitivity to environmental fluctuations. According to Zhyzhka and Povod (2019), Mykhalko and Povod (2020), and Sadovyi et al. (2025), deviations from the recommended microclimatic parameters result in reduced feed intake, impaired immune status, and poorer feed efficiency.

Modern pig production systems commonly apply the all-in/all-out management principle, which enhances biosecurity and reduces the spread of infectious diseases (Lykhach et al., 2023). In addition, grouping piglets according to body weight and minimizing regrouping events reduces stress and promotes improved growth performance (Lykhach et al., 2026).

Nutrition during the nursery period is one of the major determinants of piglet performance. Substantial changes in the digestive system accompany the transition from a milk-based diet to plant-based feeds, necessitating the use of highly digestible, high-quality feed ingredients (Lee et al., 2014; Arnaud et al., 2023; St-Pierre et al., 2023). Fabà et al. (2025) emphasized that ensuring adequate feed intake during the first days after weaning is particularly important, as it directly influences intestinal development and subsequent growth performance.

The implementation of specialized feeding strategies, including prestarter diets and creep feeding, has been shown to improve piglet survival and growth performance during the nursery period (Tishchenko et al., 2024; Moisei et al., 2025). Furthermore, nursery diets should be nutritionally balanced with respect to metabolizable energy, crude protein, essential amino acids, vitamins, and minerals to support optimal growth and physiological development (Boudry et al., 2004).

Another important area of research is the investigation of environmental factors affecting piglet survival, which depends on a combination of management, nutritional, and microclimatic conditions (Mabunda et al., 2025). The application of modern housing systems, including maintaining piglets in their familiar environment after weaning, has been shown to reduce stress and facilitate adaptation to the post-weaning period (Winters et al., 2021).

With increasing restrictions on the use of antibiotic growth promoters, considerable attention has been directed toward alternative strategies to improve pig productivity, particularly the use of probiotics (Blavi et al., 2021). According to Zheng et al. (2021) and Song et al. (2021), probiotics help maintain intestinal microbial balance, enhance immune function, and reduce the incidence of gastrointestinal disorders. Jang (2024) and Barba-Vidal et al. (2019) emphasized that Bacillus-based probiotics are particularly effective due to their high resistance to environmental stressors and their ability to produce a broad spectrum of digestive enzymes.

Studies by Mazur-Kuśnirek et al. (2023) and Leal et al. (2024) demonstrated that probiotic supplementation improves nutrient digestibility, increases average daily gain, and enhances feed efficiency. In addition, probiotics exert beneficial effects on intestinal morphology and immune status in piglets. Furthermore, multistrain probiotic formulations have been reported to provide synergistic benefits by combining the functional properties of different microbial species.

Wang et al. (2021) and Dowarah et al. (2017) reported that probiotics promote the restoration of intestinal epithelial structure following weaning, particularly by increasing villus height and reducing crypt depth, which are recognized indicators of small intestinal functionality. These morphological improvements enhance nutrient absorption and contribute to more efficient feed utilization. Similar findings were reported by Liao and Nyachoti (2017), who demonstrated that probiotic supplementation improves intestinal barrier integrity and reduces intestinal permeability.

In addition, Liao and Nyachoti (2017) and Markowiak and Śliżewska (2018) reported that probiotics play an important role in modulating both humoral and cellular immune responses. They stimulate the production of immunoglobulins, particularly secretory IgA, which is essential for protecting the intestinal mucosa against pathogenic microorganisms. Moreover, Gresse et al. (2017) emphasized that probiotic supplementation reduces intestinal colonization by opportunistic pathogens, particularly *Escherichia coli*, a principal causative agent of post-weaning diarrhea.

An equally important aspect is the effect of probiotics on productive performance. Studies by Giang et al. (2011) and Meng et al. (2010) demonstrated that dietary probiotic supplementation during the nursery period increased average daily gain by 5–12 % and improved feed conversion efficiency. Similar findings were reported by Mun et al. (2021) and Molini et al. (2022), who also observed improvements in the overall physiological status of piglets together with reduced mortality.

Considerable attention has also been given to the combined use of probiotics and prebiotics (synbiotics). According to Swanson et al. (2020), synbiotic supplementation yields more pronounced benefits by stimulating the growth of beneficial intestinal microorganisms and creating favorable conditions for their metabolic activity. This approach is particularly valuable during the post-weaning period, when

the intestinal microbiota is unstable and highly susceptible to environmental and dietary changes.

The efficacy of probiotic supplementation is strongly influenced by strain composition, dosage, and application conditions. Barba-Vidal et al. (2019), Zhu et al. (2022), and Zhang et al. (2023) emphasized that the appropriate selection of probiotic strains is essential for maximizing their beneficial effects on piglet performance. Nevertheless, Atuahene et al. (2025) reported that the magnitude of these responses may vary with housing conditions, dietary composition, and the animals' health status.

Overall, the nursery period represents a critical stage in determining the productive potential of pigs, during which housing conditions, nutritional management, and post-weaning stress strongly influence performance. In the context of increasing restrictions on the use of antibiotic growth promoters, probiotics have emerged as an effective and safe alternative for improving piglet health and productivity. Their beneficial effects include the stabilization of intestinal microbiota, enhancement of gastrointestinal function, and modulation of immune responses, which collectively improve growth performance, survival, and feed utilization efficiency. Consequently, probiotics have become an integral component of modern commercial swine production systems.

Therefore, the application of probiotics represents a promising and scientifically substantiated strategy for improving the efficiency and sustainability of pork production, highlighting the need for further research to optimize their use under commercial production conditions.

2. Materials and methods

The experimental study was conducted at Globynskyi Pig Breeding Complex LLC. The experimental animals were hybrid piglets obtained from crossbred Landrace × Large White sows inseminated with semen from PIC 337 synthetic terminal-line boars of British genetic origin. The study evaluated the effects of the probiotic feed additive Natupro, incorporated into the compound feed at a dosage of 0.5 kg/t, on the growth performance and economic efficiency of nursery piglets.

The objective of the study was to provide a scientific assessment of the feasibility of using the probiotic Natupro in nursery pig nutrition and to determine its effects on growth performance, feed utilization efficiency, and the economic outcomes of pig production.

Experimental groups were formed according to the methodology described by Ladyka et al. (2023) using the analog principle, taking into account the age and initial body weight of the animals, in accordance with the experimental design (Table 1). Two experimental groups were established: a control group and a probiotic-treated group, each comprising 480 piglets.

Piglets from both experimental groups were housed under identical production conditions in Nursery Unit No. 2 (Fig. 1).

Table 1
Experimental design

Parameter	Control group (I)	Experimental group (II)
Number of piglets, head	480	480
Feeding during the suckling period	Liquid milk replacer	
Age at the beginning of the nursery period, days	21	21
Feeding system during the nursery period	Liquid prestarter and starter compound feeds	
Housing system	Floor-pen housing, 60 piglets per pen on a fully slatted floor	
Duration of feeding the first prestarter diet, days	8	8
Age at transition to the second prestarter diet, days	29	29
Duration of feeding the second prestarter diet, days	17	17
Age at transition to the starter diet, days	46	46
Total nursery period, days	50	50
Age at the end of the nursery period, days	71	71

Fig. 1. Housing conditions of the experimental piglets

Microclimatic conditions, stocking density, and housing system were identical for both groups, ensuring the reliability of comparative analyses. Piglets were housed in pens containing 60 animals each on fully slatted floors. The available floor space was 0.33 m² per piglet, while the heated area beneath the brooder provided 0.06 m² per animal.

Throughout the nursery period, piglets in the control group were fed standard complete compound feed produced by the Globyne Feed Mill in accordance with the farm's feeding program. These included Prestarter 1 (for piglets weighing up to 9 kg), Prestarter 2 (for piglets weighing 9–12 kg), and Starter 15–30 (for pigs weighing 12–30 kg). All diets were formulated using premixes supplied by Cargill. Piglets in the experimental group received the same basal diets supplemented with the probiotic Natupro at a dosage of 0.5 kg/t of feed. The probiotic was incorporated into the feed using the automated Spotmix 2 liquid feeding system, ensuring accurate dosing and uniform distribution throughout the feed mixture.

The farm operated a liquid feeding system with a water-to-feed ratio of 2.8 L of water per 1 kg of dry compound feed, and a feeding space allowance of 8 cm per piglet. Feed residues were continuously monitored using automatic sensors, preventing excessive feed accumulation in the feeders.

Body weight was recorded using an automated weighing system. Individual piglets were weighed at the beginning and the end of the nursery period. In contrast, pen weights were recorded when animals were transferred to the subsequent feeding phase and the corresponding diet formulation.

During the experiment, the effects of Natupro supplementation on piglet growth performance during different stages of the nursery period, average daily feed intake, feed conversion ratio, survival rate, and the economic efficiency of its application were evaluated. Feed intake was recorded daily on a per-pen basis using the Spotmix 2 feeding system, enabling continuous monitoring of feed consumption and timely detection of deviations.

For all animals removed from the experiment, the date of removal, the reason for removal, and the body weight at the time of removal were recorded to ensure an accurate assessment of piglet survival.

Survival rate was also evaluated at each transition to a new dietary formulation during the nursery period.

Upon completion of the experiment, all primary data were compiled and used to calculate the principal zootechnical performance indicators, including average daily gain, total weight gain, average daily feed intake, feed conversion ratio, and survival rate.

The economic efficiency of probiotic supplementation was assessed by comparing production costs and economic returns between the control and experimental groups. The evaluation included feed costs, probiotic supplementation costs, the value of live weight gain, and economic losses associated with mortality and culling. Based on these data, net profit, the additional economic benefit of probiotic supplementation, and production profitability were determined.

To ensure the reliability of the results, all experimental data were statistically analyzed using the methods of variation statistics described by Kramarenko et al. (2019). Mean values and the standard error of the mean (SEM) were calculated, and the statistical significance of differences between the experimental groups was evaluated.

3. Results and discussion

3.1. Results

The analysis of growth performance and survival of piglets during the nursery period demonstrated a positive effect of dietary supplementation with the probiotic feed additive Natupro (Table 2).

Table 2

Growth performance and survival of piglets during the nursery period

Parameter	Control group (I)	Experimental group (II)
Initial number of piglets, head	480	479
Initial body weight, kg	6.93 ± 0.34	6.99 ± 0.16
Body weight at transition to the second prestarter diet, kg	8.56	8.73
Number of piglets at transition to the second prestarter diet, head	474	475
Mortality during the first prestarter phase, head	6	4
Survival rate during the first prestarter phase, %	98.75	99.16
Body weight at transition to the starter diet, kg	14.17	14.63
Number of piglets at transition to the starter diet, head	474	475
Survival rate during the second prestarter phase, %	100.00	100.00
Mortality during the starter phase, head	1	2
Number of piglets at the end of the experiment, head	473	473
Survival rate during the starter phase, %	99.79	99.58
Overall survival rate during the nursery period, %	98.54	98.75
Final body weight, kg	28.88 ± 0.97	29.87 ± 0.56

At the beginning of the nursery period, no substantial differences in body weight were observed between the experimental groups. The experimental group exceeded the control group by only approximately 0.9 %, confirming the successful allocation of animals according to the analog principle.

During the first prestarter feeding phase, mortality in the experimental group was reduced by two piglets, representing a 33.3 % decrease compared with the control group. Consequently, the survival rate increased by 0.41 percentage points, corresponding to a relative improvement of 0.4 %.

At the transition to the second prestarter diet, piglets receiving Natupro tended to exhibit better growth performance. Their average body weight was 0.17 kg (2.0 %) higher than that of the control animals. In addition, one more piglet remained in the experimental group at this stage, indicating better adaptation to the feeding conditions during the early nursery period.

During the second prestarter phase, survival remained at 100% in both groups, indicating stable management conditions and suggesting that the probiotic had no additional effect on survival during this period.

At the transition to the starter diet, the difference in body weight between the groups increased to 0.46 kg (3.2 %) in favor of the experimental group, suggesting a cumulative effect of probiotic supplementation on growth performance.

During the starter feeding phase, mortality was slightly higher in the experimental group, resulting in a 0.2 % lower survival rate than in the control group. Nevertheless, the overall survival rate throughout the entire nursery period remained 0.2 % higher in the experimental group.

At the end of the nursery period, the final body weight of piglets receiving Natupro exceeded that of the control group by 0.99 kg, representing a 3.4 % increase. This finding indicates that probiotic supplementation positively affected growth and metabolic processes, resulting in improved productive performance.

Overall, dietary supplementation with Natupro enhanced piglet growth performance, improved survival during the early stages of the nursery period, and increased final body weight, confirming the suitability of this probiotic as a nutritional strategy for nursery pig production.

The observed improvements in growth performance and survival warranted a more detailed evaluation of growth intensity during the different feeding phases of the nursery period. The analysis of growth performance indicators in Table 3 shows a consistent advantage for piglets receiving dietary supplementation with 0.5% Natupro throughout the experimental period.

Table 3

Growth performance of piglets during different feeding phases of the nursery period

Parameter	Control group (I)	Experimental group (II)
Total weight gain during the first prestarter phase, kg	1.63	1.74
Average daily gain during the first prestarter phase, g	203.75	217.30
Relative weight gain during the first prestarter phase, %	21.05	22.12
Total weight gain during the second prestarter phase, kg	5.61	5.90
Average daily gain during the second prestarter phase, g	374.00	393.44
Relative weight gain during the second prestarter phase, %	49.36	50.53
Total weight gain during the starter phase, kg	14.71	15.24
Average daily gain during the starter phase, g	588.4	609.6
Relative weight gain during the starter phase, %	68.34	68.49
Total weight gain during the entire nursery period, kg	21.95 ± 0.93	22.88 ± 0.52
Average daily gain during the entire nursery period, g	439.0 ± 9.6	457.6 ± 7.2
Relative weight gain during the entire nursery period, %	122.59 ± 1.03	124.15 ± 0.94

During the first prestarter feeding phase, piglets receiving Natupro exhibited an increase in average daily gain of 13.55 g (6.6 %) compared with the control group. This improvement resulted in a 0.11 kg (6.7 %) increase in total weight gain, while relative weight gain increased by 1.07 percentage points, corresponding to an improvement of approximately 5.1 %.

A similar trend was observed during the second prestarter phase. Average daily gain increased by 19.44 g (5.2 %), leading to an increase in total weight gain of 0.29 kg (5.2 %). Relative weight gain also increased by 1.17 percentage points, representing an improvement of 2.4 % compared with the control group.

During the starter feeding phase, average daily gain in the experimental group further increased by 21.2 g (3.6 %), resulting in an additional 0.53 kg (3.6 %) of total weight gain. In contrast, relative weight gain remained nearly unchanged, showing only a slight increase of 0.15 percentage points (0.2 %) compared with the control group.

Overall, during the nursery period, piglets supplemented with Natupro showed an increase in average daily gain of 18.6 g (4.2 %), resulting in an additional 0.93 kg (4.2 %) in total weight gain. Relative weight gain increased by 1.56 percentage points (1.3 %) compared with the control group.

These findings demonstrate that dietary supplementation with Natupro consistently improved growth performance throughout all feeding phases of the nursery period. The higher growth rates were accompanied by greater total weight gain, indicating more efficient utilization of dietary nutrients and improved metabolic efficiency in the experimental animals.

The enhanced growth performance observed in the experimental group was closely associated with increased feed intake and improved feed conversion efficiency, warranting a detailed evaluation of feed utilization during the different feeding phases of the nursery period.

As shown in Table 4, during the first prestarter feeding phase, average daily feed intake in the experimental group increased by 0.01 kg (4.2 %), resulting in an additional 0.11 kg of feed consumed per piglet (5.8 %) over the entire period. Owing to the superior growth performance of piglets receiving NatuPro, this increase in feed intake was accompanied by a slight improvement in the feed conversion ratio of 0.01 kg feed per kilogram of body weight gain (0.9 %).

During the second prestarter feeding phase, despite nearly identical average daily feed intake in both groups, total feed consumption in the experimental group increased slightly by 0.04 kg (0.4 %). This was accompanied by a substantial improvement in feed conversion ratio, which decreased by 0.09 kg feed/kg gain (4.6 %) compared with the control group.

During the starter feeding phase, average daily feed intake in the experimental group increased by 0.03 kg (2.9 %), resulting in an additional 0.75 kg of starter feed consumed per piglet (2.9 %) over the feeding period. Owing to the superior growth performance of piglets receiving Natupro, the feed conversion ratio improved by 0.01 kg feed/kg gain (0.6 %) relative to the control group.

Table 4
Feed intake and feed conversion during the nursery period

Parameter	Control group (I)	Experimental group (II)
First prestarter feed consumed per piglet, kg	1.89	2.00
Average daily intake of the first prestarter diet, kg	0.24	0.25
Feed conversion ratio during the first prestarter phase, kg feed/kg gain	1.16	1.15
Second prestarter feed consumed per piglet, kg	11.07	11.11
Average daily intake of the second prestarter diet, kg	0.65	0.65
Feed conversion ratio during the second prestarter phase, kg feed/kg gain	1.97	1.88
Starter feed consumed per piglet during the feeding period, kg	25.47	26.22
Average daily intake of the starter diet, kg	1.02	1.05
Feed conversion ratio during the starter phase, kg feed/kg gain	1.73	1.72
Total compound feed consumed per piglet, kg	36.12	37.48
NatuPro consumed per piglet, kg	0.00	0.19
Total feed consumed per piglet (including probiotic), kg	36.12	37.67
Overall feed conversion ratio, kg feed/kg gain	1.65	1.64

Overall, during the nursery period, piglets supplemented with NatuPro consumed 1.36 kg (3.8 %) more compound feed than the control group. Along with probiotic additive intake, total feed consumption increased by 1.55 kg (4.3 %). Despite this higher feed intake, the overall feed conversion ratio improved by 0.01 kg feed/kg gain (0.6 %), indicating more efficient utilization of dietary nutrients due to probiotic supplementation.

These findings demonstrate that supplementation with NatuPro increased feed intake and improved feed conversion efficiency, attributable to enhanced growth performance. The greatest improvement in feed utilization was observed during the second prestarter feeding phase, suggesting that probiotic supplementation was particularly effective during this stage of the nursery period.

The economic implications of these changes in feed utilization are presented in Table 5, which illustrates the close relationship between piglet growth performance, feed consumption, and the economic efficiency of probiotic supplementation.

Table 5
Feed costs during the nursery period

Parameter	Control group (I)	Experimental group (II)
Cost of the first prestarter diet per piglet, UAH	61.89	65.65
Cost of the second prestarter diet per piglet, UAH	412.59	420.71
Cost of the starter diet per piglet, UAH	270.02	277.95
Cost of NatuPro supplementation per piglet, UAH	0.00	86.20
Total feed cost per piglet, UAH	744.50	850.52
Average cost of compound feed (excluding NatuPro), UAH/kg	20.61	20.39
Average cost of feed (including NatuPro), UAH/kg	20.61	22.69
Feed cost per kilogram of weight gain, UAH/kg gain	33.92	37.17

The analysis of feed costs associated with the different dietary formulations demonstrated that both improved growth performance and supplementation with the probiotic feed additive Natupro had a substantial impact on total feeding costs.

The enhanced productive performance observed in the experimental group was accompanied by increased feed consumption, which was directly reflected in the cost of the individual dietary phases. Compared with the control group, expenditures on the first prestarter diet increased by UAH 3.76 (6.1 %), those on the second prestarter diet by UAH 8.12 (2.0 %), and those on the starter diet by UAH 7.93 (2.9 %). These results are consistent with the previously observed increases in average daily gain and total weight gain in piglets receiving Natupro.

An additional factor influencing the economic outcomes was the inclusion of Natupro at a rate of 0.5 %, which generated an extra cost of UAH 86.20 per piglet. Although this additional expense was relatively moderate compared with previous experimental evaluations, it contributed substantially to the increase in total feeding costs.

Consequently, total feed costs in the experimental group exceeded those of the control group by UAH 106.02 (14.2 %). This finding indicates that the improvement in growth performance was accompanied not only by greater feed consumption but also by higher feeding costs resulting from probiotic supplementation.

The average cost per kilogram of feed provides further insight into the economic efficiency of the feeding program. Excluding the cost of Natupro, the average feed price in the experimental group was UAH 0.22/kg (1.1 %) lower than in the control group, indicating that the basal diets had essentially comparable costs. However, after the inclusion of the probiotic, the average feed cost increased by UAH 2.08/kg (10.1 %), substantially affecting overall production costs.

The most comprehensive indicator of feeding efficiency is the feed cost per kilogram of body weight gain. In the experimental group, this value increased by UAH 3.25/kg gain (9.6 %), indicating that the additional expenditures associated with feed and probiotic supplementation exceeded the proportional increase in productive performance. In other words, although piglets supplemented with Natupro achieved faster growth, the feed cost required to produce each kilogram of body weight gain was higher.

Overall, these results demonstrate a clear relationship between growth performance, feed intake, and feeding costs.

On the one hand, dietary supplementation with Natupro stimulated growth and increased feed consumption; on the other hand, it resulted in higher total feeding costs and a greater feed cost per kilogram of gain. These findings highlight the importance of evaluating probiotic supplementation from both biological and economic perspectives, considering the balance among production costs, growth performance, and economic return.

The overall economic efficiency of Natupro supplementation is presented in Table 6. Although the probiotic increased feeding costs, its use had an overall positive effect on final production and economic performance in nursery piglets, supporting its practical use under commercial swine production conditions.

Table 6
Economic efficiency of probiotic supplementation with Natupro during the nursery period

Parameter	Control group (I)	Experimental group (II)
Initial value of one piglet at the beginning of the nursery period, UAH	1,142.76	1,152.65
Operating cost of rearing one piglet during the nursery period, UAH	1,057.99	1,102.82
Total operating cost per piglet at the end of the nursery period, UAH	2,200.75	2,255.47
Operating cost per kilogram of live body weight at the end of the nursery period, UAH/kg	76.20	72.96
Market value (excluding VAT) of one piglet at the end of the nursery period, UAH	3,350.08	3,464.92
Profit per piglet during the nursery period, UAH	1,149.33	1,209.45
Profitability of nursery pig production, %	52.22	53.62

The initial value of piglets at the beginning of the nursery period was UAH 9.89 (0.9 %) higher in the experimental group than in the control group, a difference that had only a negligible effect on the overall cost structure. In contrast, the operating cost of rearing one piglet during the nursery period increased by UAH 44.83 (4.2 %), primarily due to higher feeding expenses associated with probiotic supplementation and increased feed consumption.

Consequently, the total operating cost per piglet at the end of the nursery period was UAH 54.72 (2.5 %) higher in the experimental group than in the control group, indicating a moderate increase in production costs resulting from the use of Natupro.

A more informative indicator of production efficiency is the operating cost per kilogram of live body weight. In the experimental group, this value was UAH 3.24/kg (4.3 %) lower than in the control group. This improvement can be attributed to the superior growth performance of piglets receiving Natupro, which enabled production costs to be distributed more efficiently over a greater body weight gain, thereby partially offsetting the increase in total operating costs.

The improved productive performance also enhanced the market value of the animals. At the end of the nursery period, the market value of piglets in the experimental group exceeded that of the control group by UAH 114.84 (3.4 %), reflecting their greater final body weight.

As a consequence, profit per piglet increased by UAH 60.12 (5.2 %) in the experimental group. Likewise, production profitability increased by 1.40 percentage points, corresponding to a relative improvement of 2.7 %.

Overall, despite increased operating costs, dietary supplementation with Natupro improved the final economic performance of nursery pig production by enhancing animal productivity. These findings indicate that the economic value of probiotic supplementation depends on the balance between the additional costs associated with its inclusion in the diet and the corresponding improvement in productive performance, which was sufficient to offset these costs and generate additional profit.

3.2. Discussion

The findings of the present study generally support current evidence regarding the beneficial effects of probiotic supplementation in nursery pig nutrition. Nevertheless, their interpretation requires careful consideration of both biological responses and economic outcomes.

The observed improvement in growth performance of piglets receiving Natupro (3.6–6.6 %) is consistent with the findings of Giang et al. (2011), Meng et al. (2010), and Mun et al. (2021). However, the magnitude of the response was lower than the maximum improvements (up to 10–12%) reported in previous studies. This suggests that the probiotic Natupro exerted a moderate growth-promoting effect under the conditions of the present experiment, or that the production environment limited its full biological potential. This interpretation is consistent with the conclusions of Barba-Vidal et al. (2019), Zhu et al. (2022), and Pereira et al. (2022), who emphasized that the efficacy of probiotics varies considerably depending on strain characteristics, dietary composition, and production conditions.

The improvement in piglet survival observed in the experimental group was relatively small, indicating that the probiotic had only a limited effect under conditions of already high veterinary management and health status. This finding differs somewhat from the results reported by Zheng et al. (2021), Gresse et al. (2017), and Jiang et al. (2024), who described more pronounced reductions in disease incidence following probiotic supplementation. Such discrepancies suggest that the benefits of probiotics may depend largely on the animals' initial health status and the intensity of environmental and management-related stressors.

The improvement in feed conversion ratio was also relatively modest (approximately 0.6 %) and lower than that reported by Mazur-Kuśnirek et al. (2023) and Leal et al. (2024). One possible explanation is the high nutritional quality of the basal diets used in the present study, which may have limited the potential for further improvements in nutrient utilization.

The economic evaluation provides additional insight into the practical significance of these findings. Although enhanced growth performance was accompanied by higher feed intake, total feeding costs in the experimental group increased by 14.2 %, partly due to the inclusion of Natupro

in the diet. Consequently, the feed cost per kilogram of body weight gain increased by 9.6 %, indicating that the increase in feeding costs exceeded the proportional improvement in productive performance.

At the same time, the overall economic assessment presents a more balanced perspective. Despite increases in the operating cost of rearing one piglet during the nursery period (4.2 %) and in total production cost (2.5 %), the operating cost per kilogram of live body weight decreased by 4.3 %. This improvement reflects the higher growth rate of piglets receiving Natupro, which allowed production costs to be distributed more efficiently across a greater amount of live weight produced.

An important criterion in the economic evaluation is that the greater final body weight achieved by piglets receiving Natupro increased their market value by 3.4 %, resulting in a 5.2 % increase in profit and a 2.7 % improvement in production profitability. Therefore, the economic benefits of probiotic supplementation were derived primarily from enhanced animal productivity rather than from reduced production costs.

Nevertheless, the observed economic advantage should be interpreted with caution, as it was relatively modest and may be sensitive to fluctuations in market conditions, particularly changes in feed prices or the cost of the probiotic itself. An increase in the price of Natupro or a decline in the market value of pigs could reduce or even eliminate the economic benefit of its application.

Another limitation of the present study is the absence of detailed investigations into the biological mechanisms underlying the observed responses. In particular, intestinal microbiota composition, intestinal mucosal morphology, and immunological parameters were not evaluated, limiting the ability to explain the observed improvements from the perspective of contemporary gastrointestinal physiology and host–microbiota interactions (Liao & Nyachoti, 2017; Wang et al., 2021).

Furthermore, the experiment was conducted at a single commercial farm operating under high standards of technological and management practices. Consequently, caution should be exercised when extrapolating these findings to production systems with different management practices, housing conditions, or dietary formulations (Barba-Vidal et al., 2019).

Overall, the results of the present study support the potential of Natupro as a probiotic feed additive for nursery piglets, while indicating that its effects are moderate rather than dramatic. The biological benefits were expressed primarily as improved growth performance and modest enhancement of feed utilization efficiency. In contrast, the economic advantages resulted mainly from increased final productivity rather than reduced production costs. These findings highlight the need for further studies to optimize probiotic dosage, application strategies, and economic efficiency across different commercial production conditions.

It is also important to emphasize that the improvement in growth performance observed during the early nursery period may have implications beyond this production stage. Early post-weaning growth is a key determinant of subsequent finishing performance, as greater weight gains during the nursery phase contribute to improved gastrointestinal development, enhanced feed efficiency, and more consistent growth throughout later production stages. Consequently, improving piglet performance immediately after weaning may ultimately enhance overall productivity and the economic sustainability of commercial pork production.

4. Conclusions

Dietary supplementation with 0.5 % Natupro during the nursery period improved piglet growth performance, increasing average daily gain by 3.6–6.6 %, total weight gain by 4.2 %, and final body weight by 3.4 %.

Probiotic supplementation exerted a positive effect on the physiological status and survival of nursery piglets; however, the magnitude of this response was moderate, indicating that management practices, housing conditions, and the baseline health status of the animals strongly influence its effectiveness.

Supplementation with Natupro increased feed intake and slightly improved feed conversion ratio (approximately 0.6 %). However, it also increased total feeding costs by 14.2 %. It raised the feed cost per kilogram of body weight gain by 9.6 %, indicating that the increase in production costs exceeded the proportional improvement in productive performance.

Despite the higher production costs, supplementation with Natupro reduced the operating cost per kilogram of live body weight by 4.3 %. It increased the market value of nursery pigs by 3.4 %, resulting in a 5.2 % increase in profit and a 2.7 % improvement in production profitability. These findings indicate that the economic benefits of probiotic supplementation stem primarily from improved growth performance rather than reduced production costs.

Conflict of interest

The authors declare no conflict of interest.

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