

IMPACT OF *Bacillus subtilis* AND *Bacillus licheniformis* SUPPLEMENTATION ON REPRODUCTIVE AND PRODUCTIVE QUALITIES OF SOWS

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ABSTRACT: In modern livestock management, biotechnological products, including feed additives, are widely utilized to enhance productivity. One such agent is probiotics, which have been employed for a long time in both human food and livestock. Their effects are based on various biological mechanism—including the reduction of intestinal acidity, inhibition of pathogenic microorganisms, and stimulation of the immune response. Unlike antibiotics, which are prohibited in animal feed, probiotic supplements are regarded as safe alternatives for maintaining animal health and prophylaxis disease. In particular, in the diets of sows, probiotics contribute to the improvement of overall physiological condition and stimulate the development of beneficial intestinal microflora. Consequently, there has been increasing interest in studying effective probiotic bacteria and developing advanced biotechnological preparations. Among promising candidates are probiotics based on *Bacillus subtilis* and *Bacillus licheniformis*, which have been evaluated in various animal species for their potential beneficial effects on host physiology. The use of such probiotic feed additives has demonstrated favorable effects in sows across different ages and physiological stages. The administration of this probiotic for both young and adult animals during periods of preparation for fertilization, as well as before and after farrowing, positively affected their reproductive function. Improvements were observed in indicators such as sexual reflex expression, fertilization rates, litter size, and the number of live births. Additionally, significant enhancements in growth, weight gain, and the survival of piglets up to two months of age were recorded. The optimal doses of probiotic use were determined to be 1.0% of the daily ration for young sows and 1.5% for adults. Therefore, the results of this study substantiate the inclusion of a probiotic supplement combining these two bacteria in the diets of sows to enhance their productivity and the quality of their offspring.

Keywords: Biotechnological products, Gastrointestinal microflora, Immune system, Probiotics, Sows, Reproductive capacity.

INTRODUCTION

Managing the reproductive function of sows to increase the production of meat in accordance with consumers demand is influenced by numerous factors. The reproductive cycle affects the overall condition of sows, the manifestation of estrus after farrowing and subsequent meat productivity. Therefore, intestinal nutrient absorption and immunity are of great importance and require an optimal balance of the intestinal microflora (Gardiner et al., 2020; Szabó et al., 2023). Such balance can be achieved through the administration of probiotics, defined as live microorganisms which, when administered in adequate amounts, confer a health benefit on the host (Kritas et al., 2015).

Probiotics exert their beneficial effects through various mechanisms, including the reduction of intestinal pH, competitive exclusion of pathogenic microorganisms, and modulation of the host immune response (Hu et al., 2021). Moreover, unlike antibiotics, which are banned in animal feed production in several countries, probiotic additives offer an alternative means of improving productivity and preventing disease in sows by promoting overall health and increasing beneficial microbial populations (Pereira et al., 2022). The use of probiotics, antimicrobial metabolites of beneficial microorganisms, or other biotechnological products represents a sustainable approach to enhance animal health and modulate intestinal function. This, in turn, may reduce reliance on antimicrobial agents and support globally to limit the spread of antimicrobial resistance (O'Connor et al., 2020).

According to Mazur-Kuśnirek et al. (2023), the weaning process can be particularly stressful for piglets because it involves separation from the sow and a dietary transition from milk to plant-based feed. Such stress factors may adversely affect the immune system and disrupt the intestinal microbiota balance, leading to gastrointestinal disorders, infections and diarrhea. Zhu et al. (2022) reported that *Lactobacillus* species improve growth rates and reduce diarrhea incidence in piglets by enhancing nutrient digestibility and intestinal barrier function. Among available probiotics, *Lactobacillus* species are considered among the most promising alternatives and are regarded as safe substitutes for antibiotic use in pig husbandry. Hayakawa et al. (2016) also indicated that the most significant impact of probiotics on the intestinal microbiota and host animals occurs when they are included in the diet during stressful periods, such as

weaning or early lactation. Likewise, [Saladrigas-García et al. \(2022\)](#) demonstrated that supplementing sow feed with probiotics particularly *Bacillus amyloliquefaciens* may benefit fertility. Daily feeding of *B. amyloliquefaciens* was associated with an increased number of weaned piglets. Strong correlations between the microbiota composition of sows and their piglets increased maternal imprinting, with effects persisting beyond weaning. [Liu et al. \(2025\)](#) reported that the intestinal microbiota might influence the return to estrus in sows after weaning through its effects on sex hormones, suggesting its potential for identifying sows with superior reproductive performance. Additionally, [Chang et al. \(2024\)](#) recommended supplementing sows with yeast-derived postbiotics from late pregnancy through lactation to help regulate the intestinal microbiota of both sows and piglets, thereby improving overall health and resilience during the weaning period.

In addition, the prohibition of antibiotics and zinc oxide, which is an extremely effective antimicrobial agent that plays a key role in alleviating intestinal pathologies and dysbiosis associated with piglet weaning, has stimulated the search for new alternative dietary interventions that support health and development. To date, most studies have focused on post-weaning diets. However, maternal dietary intervention offers a promising alternative. Supplement to sows during pregnancy and lactation with microbiological additives can promote intestinal development and improve offspring health before weaning, thereby enhancing productivity and resilience immediately after weaning and later in life ([Kiernan et al. 2023](#)).

A large group of probiotic bacteria is based on the *Bacillus* genus, among which *Bacillus subtilis*, *Bacillus coagulans*, *Bacillus pumilus*, *Bacillus licheniformis* and *Bacillus clausii* are frequently studied. These species are of growing scientific interest and hold strong potential for industrial application. Moreover, probiotic spore-forming agents such as *B. subtilis* and *B. licheniformis* are ideal model microorganisms capable of surviving stabilization methods used in producing powdered products, such as lyophilization or drying, including cell dehydration. Modern trends in probiotic delivery involve various microencapsulation techniques, which can considerably increase cell viability during freezing or drying processes ([Łubkowska et al., 2023](#)).

According to [Li et al. \(2025\)](#), supplementation with *B. subtilis* and *B. licheniformis* significantly reduced the number of low-birth-weight piglets and the incidence of diarrhea and increased the frequency of successful weaning. These outcomes were accompanied by higher nutrient and immunoglobulin levels in colostrum. In addition, probiotic supplement modulated the microbiota composition of both the sows and their piglets, promoting vertical transmission of beneficial bacteria such as Verrucomicrobiota and Akkermansia. Moreover, the probiotic supplement improved the expression of glucose and amino acid transporters in the placenta and enhanced the activity of the mTOR signaling pathway.

The search for new biotechnological products and probiotic formulations remains relevant in Ukraine. A new domestically developed probiotic supplement used in the present study contains *B. subtilis* and *B. licheniformis* along with the enzymes protease and lipase. Its effectiveness in animals of different species has been under investigation [Sidashova et al. \(2022\)](#), used this probiotic in bee feed and found that it increased the survival of bees during wintering. [Pogranichniy et al. \(2023\)](#) reported that feeding this probiotic to black-and-brown dairy cows improved not only milk yield, fat content, and general health, but also enhanced stress resistance and serum biochemical parameters. According to [Kananykhina and Turpurova \(2024\)](#) proteases help animals absorb nutrients more efficiently from feed. The authors suggest that this enzyme-probiotic complex exerts a multifaceted effect on the digestive tract, particularly in the rumen. [Tsvihun et al. \(2025\)](#) further revealed that the use of this probiotic in feeding dairy *Lacaune* lambs led to a 16.1% increase in average daily weight gain, a 15.8% rise in total protein content, and a 35.4% increase in globulin levels, indicating enhanced immune resistance.

According to the review of literatures, no available studies have yet been conducted on the use of probiotic supplements in sows during farrowing and lactation. This gap has generated interest in investigating the effects of a therapeutic and prophylactic probiotic supplement containing *Bacillus subtilis* and *Bacillus licheniformis* on the reproductive performance of sows of different physiological stages.

MATERIALS AND METHODS

Materials

At the private agricultural enterprise "Techmet-Yug", 30 young pigs (8 months old, 120-125 kg) and 30 adult sows (2.5-3 years old, 190-200 kg) were selected for the study. Animals were divided into three groups for each category (young pigs and adult sows), with 10 animals per group, based on the principle of analogues. The study was conducted in two stages, as depicted in Figure 1.

Components of probiotic supplement

One kilogram of the preparation contained the following active ingredients: *B. subtilis* and *B. licheniformis* bacteria, with a minimum concentration of 6×10^{12} CFU/kg (6×10^9 CFU per g); xylanase, 300,000 units/kg; protease, 5,000 units/kg; and amylase, 1,000 units/kg.

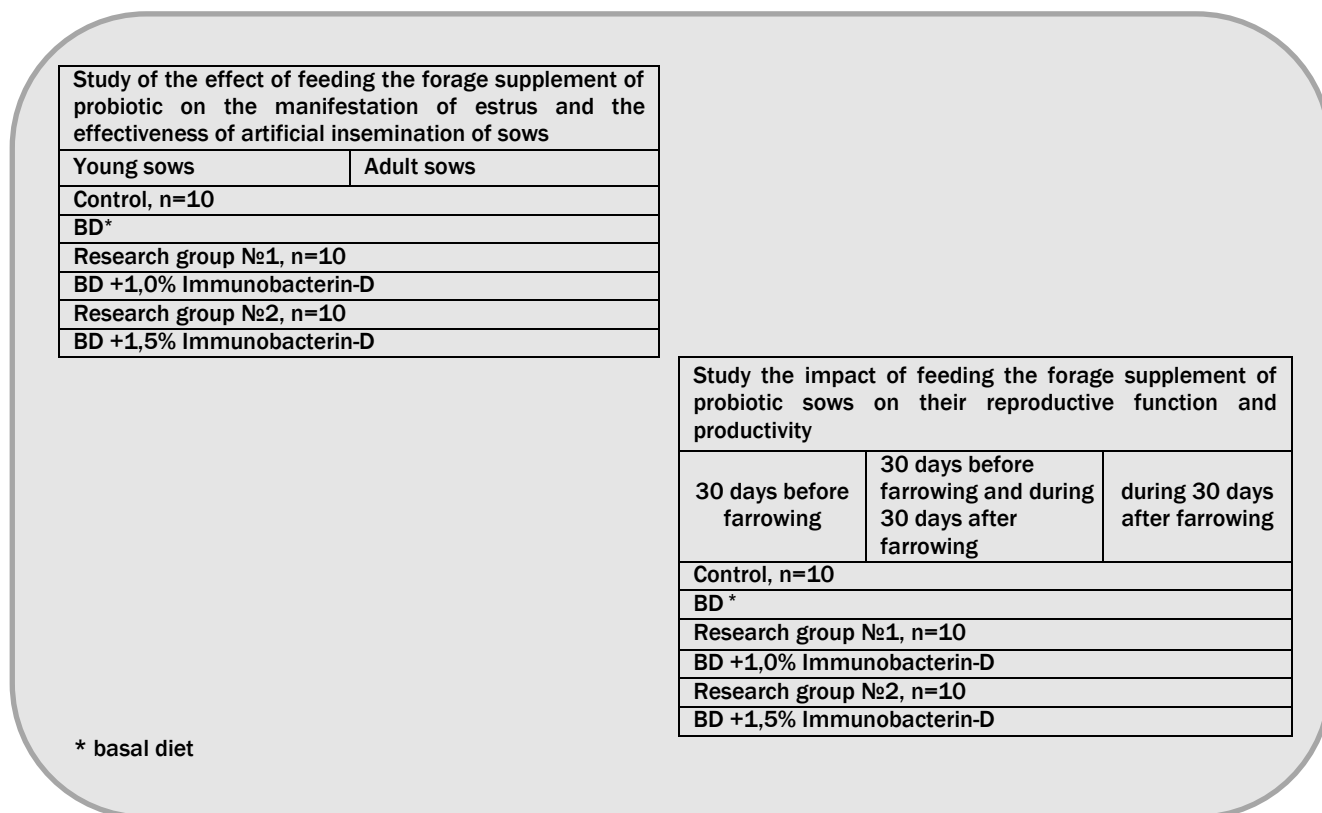


Figure 1 - Scheme of studies conducted.

Methods

The study utilized a balanced analogue group design with adult sows (selected 1 month prior to their expected farrowing). Three groups of 10 sows each were formed. The first group (control) received a traditional diet that met established feeding standards and was balanced for all nutrients. Sows in the experimental groups (second and third) received the probiotic supplement mixed with their feed for 30 days before farrowing and for 30 days postpartum, at inclusion rates of 1.0% and 1.5%, respectively.

Following farrowing, sows were selected based on the balanced analogue group principle, and three groups of 10 sows each were formed. All experimental sows were maintained under identical conditions, but their feeding regimens differed. Sows in the control group (first) received a diet balanced for all nutrients. Sows in the experimental groups (second and third) were supplemented with the probiotic feed additive at rates of 1.0% and 1.5% (w/w), respectively, for one month postpartum. The probiotic mixture was prepared as follows: For a 1.0% inclusion rate, 10 grams of probiotic were weighed and thoroughly mixed with 100 grams of concentrate. This mixture was then added to 1 kilogram of concentrate and blended well. Subsequently, an additional 9 kilograms of concentrate were added and mixed thoroughly. Finally, the total concentrate mass was brought to 100 kg, ensuring all components were well incorporated. A similar procedure was followed for the 1.5% inclusion rate. The control group did not receive any probiotic supplementation.

The growth intensity of the experimental piglets was monitored through individual weighing at birth, at 1 month of age, and at 60 days of age. Average daily weight gain was calculated using the conventional method. To assess growth and development, morphometric measurements were taken on the day of weighing, including height at the withers, chest girth (behind the shoulder blades), chest width (behind the shoulder blades), chest depth, and body length. Body structure indices were calculated from these measurements (Putra and Ilham, 2019).

The following reproductive parameters were evaluated: percentage of sows exhibiting estrus; fertilization rate (calculated as the number of confirmed pregnancies divided by the number of inseminations); number of live-born piglets per sow; number of stillborn piglets; litter mortality up to 30 days postpartum; and farrowing interval (days) (Khalak et al., 2022). Metritis, mastitis, and agalactia (MMA) syndrome in sows were diagnosed through clinical examination post-farrowing. This included monitoring body temperature, assessing feed intake, observing vaginal discharge (purulent, mucous, or with an unpleasant odor), and performing udder palpation 12–24 hours after farrowing (Büttner et al., 2024).

Statistical analysis

All statistical analyses were performed according to the methodologies described in the manuals of Klein and Moeschberger (2003) and Machin et al. (2006) using the Analysis of Molecular Variance JAMOVI software v. 2.6.19 (Navarro and Foxcroft, 2025).

RESULTS AND DISCUSSION

One of the approaches that enhances the nutritional adequacy of farm animals is the use of biotechnological preparations or feed additives with a broad biological spectrum of action. Among these additives are bacterial-based probiotics that serve both therapeutic and nutritional purposes. Such probiotics can be effectively used as complete feed additives that, through the activity of *Bacillus* spp., inhibit the growth of pathogenic and toxin-producing bacteria in feed, create favorable conditions for digestion, improve feed utilization efficiency, reduce the effects of toxins on the animal's body, and stimulate metabolic activity and overall vitality. Pogranichniy et al. (2023). The use of probiotic feed additives in livestock diets is therefore considered a relevant and practically significant area of research. In this study, the effect of feeding probiotic supplements on the manifestation of estrus and the efficiency of insemination in young and adult sows was investigated.

The inclusion of probiotic feed additive (1.0% and 1.5% of the main diet) in feeding young sows resulted in an increased manifestation of estrus by 10.0% and 20.0%, respectively, compared with the control group. However, the effect of probiotic supplementation on the duration of estrus in young sows was not statistically significant, as the duration in animals of the control group and experimental group No. 2 was identical (53 hours), and in sows of experimental group No. 3 it was 54 hours (Table 1).

Table 1 - The impact of probiotic feed additive on the manifestation of estrus and efficiency.

Indicator	Research group	№1 (control)	№2	№3
	Number of animals, heads		10	10
Came in estrus for 21 days	Heads	6	7	8
	%	60.0	70.0	80.0
The duration of estrus, hrs		53	53	54
The number of sows that were inseminated, heads		6	7	8
The number of sows that were farrowing	Heads	3	5	5
	%	50.0	71.43	62.5
Duration of farrow		2 hrs 20 min	2 hrs 14 min	2 hrs 21 min
Time between the birth of piglets, min		15	14	15
Obtained pigs, heads	Total	28	48	47
	For 1 farrow	9.3 ± 5.49	9.6 ± 4.25	9.4 ± 4.26
Manifestation, kg		1.2 ± 2.06	1.2 ± 1.57	1.2 ± 1.59

The results also indicated that feeding young pigs with the probiotic contributed to an increase in sow fertilization rates by 21.43% and 12.5%, with respective increases of 3.23% and 1.08% in comparison with the control group. In contrast, the feeding of probiotic supplements did not significantly influence fertilization rates among adult sows. Additionally, the duration of farrowing among sows in the experimental groups was unaffected by probiotic supplementation, with piglets being born at intervals of approximately 14–15 minutes. Overall, these results suggest that dietary inclusion of the probiotic was associated with heightened estrus manifestation, improved fertilization rates, and increased litter size in young sows. The best insemination results were achieved when young sows received the probiotic supplement at a concentration of 1.0% in addition to their main diet. Similar trials were conducted with adult sows.

When adult sows were given probiotic supplementation (1.0% and 1.5% of the main diet) after weaning, the manifestation of sexual reflexes increased by 10.0% in both experimental groups compared with the control group (Table 2). The effect of probiotic addition on the duration of estrus was not statistically significant, as sows in the control and experimental group No. 2 exhibited estrus for 61 hours, while sows in group No. 3 showed estrus for 62 hours. Feeding adult sows the probiotic supplement at 1.0% and 1.5% concentrations during their preparation for fertilization increased the fertilization rate by 1.39% and improved litter size (multiple births) by 9.33% and 10.59%, respectively. This led to an increase in total piglets born from 10 sows by 25.0% and 26.3%, respectively. Differences among experimental groups in farrowing duration were not significant, indicating that this parameter was independent of probiotic supplementation. Piglets were born at intervals of 15–16 minutes in all groups. Feeding sows during lactation is one of the most influential factors affecting their entire production cycle and farm productivity. Adequate nutrition during lactation influences milk production, piglet viability, and body weight at weaning. It also impacts fertility and litter size in subsequent reproductive cycles, body reserves, and the overall longevity of sows. Milk production increases gradually after farrowing, reaching its peak approximately two weeks into lactation. It is generally accepted that feeding during lactation should follow a rising feed curve after farrowing, reaching its maximum in the second week of lactation.

Balanced nutrition is crucial for providing adequate growth for both the sow and her offspring until weaning. Insufficient growth in sows can lead to lower live weight post-lactation and prolonged estrus periods. Conversely, excessive obesity is undesirable, as obese sows exhibit poor feed intake during lactation, produce less milk, lose significant weight, and are often culled prematurely (Povod et al., 2024). Common issues in swine production include an increasing number of stillbirths, prolonged farrowing durations, endometritis, mastitis, agalactia, hypogalactia, high piglet mortality, reduced weaning weights, and delayed or absent estrus post-weaning (Kramarenko et al., 2024).

The supplementary introduction of a probiotic to the sows diet one month prior to expected farrowing, at rates of 1.0% and 1.5%, increased the number of live-born piglets by 2.9% and 1.9%, respectively, compared to the control group. This improvement is attributed to a reduction in the number of stillbirths in the experimental groups (No. 2 and 3) by 1.86% and 0.95%, respectively (Table 3).

Table 2 - The Impact of probiotic feed additive on estrus and efficiency of insemination of adult sows

Indicator	Research group	№1 (control)	№2	№3
	Number of animals, heads		10	10
Came in estrus for 21 days	Heads	8	9	9
	%	80.00	90.00	90.00
The duration of estrus, hrs		61	61	62
The number of sows that were inseminated, heads		8	9	9
The number of sows that were farrowing	Heads	7	8	8
	%	87.50	88.89	88.89
Duration of farrow		2 hrs 46 min	2 hrs 51 min	2 hrs 53 min
Time between the birth of piglets, min		16	15	15
Obtained pigs, heads	Total	72	90	91
	For 1 farrow	10.29 ± 1.481	11.25 ± 1.174	11.38 ± 1.237
Manifestation, kg		1.2 ± 0.20	1.3 ± 0.19	1.3 ± 0.19

Table 3 - The probiotic feed additives at 30 days before sow productivity

Indicator	Research group	№1 (control)	№2	№3
	Number of animals, heads		10	10
Live weight of sows 30 days before farrowing, kg		196.0 ± 2.1	197.5 ± 0.8	198.3 ± 2.5
Live weight of sows 30 days after farrowing, kg		181.6 ± 3.82	182.1 ± 3.45	182.8 ± 1.05
Average daily feed consumption with sowing sows, kg		3.17	3.17	3.17
Feed units		3.4	3.4	3.4
Crude protein, g		366	366	366
Lysine, g		14.5	14.5	14.5
Obtained pigs, heads				
Total		109	110	110
Living		104	107	106
Dead		5	3	4
Alive on 1 farrow		10.4	10.7	10.6
% of the stillbirth		4.59	2.73	3.64
Nest weight on day 21, kg		43.7 ± 1.77	49.2 ± 1.54*	50.1 ± 1.62*
The average live weight of a pig at birth, kg		1.26 ± 0.011	1.35 ± 0.017***	1.36 ± 0.016***

* P≤0.05; ** P≤0.01; ***P≤0.001

Nest weight on day 21 in experimental groups №2 and № 3 also increased by 12.59% and 14.65% compared to the control group. In addition, feeding the probiotic supplement 30 days before planned farrowing contributed to an increase in piglet birth weight by 7.14% and 7.94% in groups' No. 2 and No. 3, respectively, compared to the control group. The average daily feed consumption of sows across all groups did not differ, remaining at 3.17 kg or 3.4 feed units. All sows received 366 g of crude protein and 14.5 g of lysine. The total number of piglets born across all groups was similar, ranging from 109 to 110. Notably, the control group had the lowest number of live-born piglets (104), while the groups receiving the probiotic had higher numbers (107 and 106, respectively). The incidence of stillborn piglets in the control group was 5, representing the highest stillbirth percentage (4.59%). In experimental groups No. 2 and No. 3, where the probiotic supplement was administered, the number of stillborns was lower (3 and 4, respectively), with their proportion decreasing to 2.73% and 3.64%. The average number of live piglets per farrowing in the control group was 10.4, while in the experimental groups this figure was higher - 10.7 and 10.6. These results collectively indicate a positive effect of the probiotic supplement on sow reproductive performance, evidenced by an increased number of live-born piglets and a reduced rate of stillbirths.

The growth and survival of piglets up to 2 months of age were assessed in relation to the administration of the probiotic feed additive to sows 30 days prior to farrowing (Table 4). The supplementary inclusion of varying amounts of probiotic in the sows' diet a month before farrowing also influenced piglet live weight at birth and subsequent growth, as well as their survival up to 2 months of age.

Table 4 - The Influence of probiotic feed additives 30 days before farrowing on growth and survival of piglets

Indicator	Research group	№1 (control)	№2	№3
Number of animals, heads		104	107	106
The average live weight of piglets, kg	At birth	1.26 ± 0.011	1.35 ± 0.017***	1.36 ± 0.016***
	In 2 months	16.7 ± 0.21	17.5 ± 0.25*	17.6 ± 0.24*
Mortality of piglets up to 2 months	heads	9	9	8
	%	11.65	7.55	8.45
Weaned piglets per sow, heads		9.1 ± 0.54	9.8 ± 0.35	9.8 ± 0.42
Average daily increase in piglets from birth to 2 months, kg		0.26 ± 0.501	0.27 ± 0.500	0.27 ± 0.500
Gross increase in 2 months, kg		15.44 ± 0.59	16.15 ± 0.77	16.24 ± 0.28

* P≤0.05; ** P≤0.01; ***P≤0.001

Specifically, when the probiotic additive was used in the sow rations 30 days before farrowing at concentration of 1.0% and 1.5%, the live weight of piglets at birth increased by 7.14% and 7.94% in experimental groups' No. 2 and 3 respectively. By 2 months of age, the live weight in these groups had increased by 4.79%. The average daily weight gain of piglets from birth to 2 months of age in the second and third research groups increased by 4.67% and 5.45%, respectively, compared to the first (control) group. The gross increase in piglet live weight over the 2-month period in experimental groups' No. 2 and 3 was also higher, by 4.6% and 5.18%, compared to the control. The number of weaned piglets per sow increased by 7.69% in the groups receiving the feed additive compared to the control. Furthermore, in the experimental groups (No. 2 and 3), piglet mortality up to 2 months of age decreased by 4.64% and 3.67%, respectively, compared to the control group. The study also examined the effect of administering probiotic feed additive to sows 30 days before farrowing and continuing for 30 days after farrowing on their reproductive function and productivity (Table 5). Sows that received the probiotic feed additive during this extended period showed an increase in the number of live-born piglets at birth. Additionally, the live weight of piglets at birth in groups' No. 2 and 3 increased by 5.51% and 6.30%, respectively, compared to the control group. It is plausible that the increased birth weight and number of piglets in the experimental groups are due to the probiotic feed additive promoting enhanced development and survival of piglets during the final month of gestation. Nest weight on day 21 in experimental groups' No. 2 and 3 increased by 8.31% and 13.03% compared to the control. The average daily feed consumption of farrowing sows across all groups remained consistent at approximately 3.2 kg or 3.3 feed units. This intake provided a nutritional profile of 367 g of crude protein and 14.6 g of lysine.

Table 6 presents the growth and survival of piglets up to two months of age, dependent on the introduction of the probiotic feed additive to the sows' rations 30 days before farrowing and continuing for 30 days after farrowing. The inclusion of varying amounts of the probiotic feed additive in the sows' diet during this period affects piglet mass at birth and their subsequent growth, as well as piglet mortality up to two months of age.

When probiotic supplements were used in the feeding of sows, starting 30 days before expected farrowing and continuing for 30 days after, the live weight of piglets at birth in experimental groups No. 2 and 3 (receiving 1.0% and 1.5% of the feed supplement, respectively) increased by 5.51% and 6.30% compared to the control group. This positive effect on live weight was also observed at 2 months of age. From birth to 2 months, the average daily gain in live weight of piglets in experimental groups' No. 2 and 3 increased by 10.63% and 11.42%, respectively, compared to the control. Similarly, in these groups, the mortality of piglets up to 2 months of age decreased by 2.27% and 2.35%, respectively, compared to the data obtained in the control group.

The prevention of diseases in sows after farrowing is a critical aspect, as this period is vital for the health of both sows and piglets. Preventing diseases in sows after farrowing significantly influences the quantity and quality of mammary and gland secretion, which leads to a reduction in sickness among young piglets during the postnatal period and an increase in their viability. In this regard, it is noteworthy that the addition of the probiotic feed additive to the diet of sows has a positive effect on preventing their incidence of disease in the early postpartum period. Clinical examinations of the sows revealed disease incidence across all experimental groups; however, the control group exhibited a higher incidence rate of 20.0%, which was 10.0% greater than that observed in experimental groups' No. 2 and 3, where the incidence was 10.0% (Table 7).

Table 5 - The probiotic feed additives 30 days before farrowing and continued for 30 days after farrowing on a reproductive function and sows performance

Indicator	Research group	№1 (control)	№2	№3
Number of animals, heads		10	10	10
Live weight of sows 30 days before farrowing, kg		196.2 ± 2.10	197.1 ± 2.82	198.2 ± 2.51
Live weight of sows 30 days after farrowing, kg		181.7 ± 3.82	181.8 ± 3.45	182.6 ± 1.05
Average daily feed consumption with sowing sows, kg		3.2	3.2	3.2
Feed units		3.3	3.3	3.3
Crude protein, g		367	367	367
Lysine, g		14.6	14.6	14.6
Obtained pigs, heads				
Total		111	111	112
Living		103	107	108
Dead		8	4	4
Alive on 1 farrow		10.3	10.7	10.8
% of the stillbirth		7.21	3.60	3.54
Nest weight on day 21, kg		44.5 ± 1.02	48.2 ± 1.34*	50.3 ± 1.62**
The average live weight of a pig at birth, kg		1.27 ± 0.43	1.34 ± 0.78	1.35 ± 0.81

* P≤0.05; ** P≤0.01; ***P≤0.001

Table 6 - The Impact of probiotic feed additive 30 days before farrowing and during 30 days after farrowing on the growth and survival of piglets

Indicator	Research group	№1 (control)	№2	№3
Number of animals, heads		103	107	108
The average live weight of piglets, kg	At birth	1.27 ± 1.103	1.34 ± 1.112	1.35 ± 1.110
	In 2 months	16.5 ± 3.66	18.2 ± 3.73	18.3 ± 3.72
Mortality of piglets up to 2 months	heads	11	9	9
	%	10.68	8.41	8.33
Weaned piglets per sow, heads		9.2 ± 2.85	9.8 ± 2.87	9.9 ± 2.87
Average daily increase in piglets from birth to 2 months, kg		0.25 ± 0.492	0.28 ± 0.511	0.28 ± 0.508
Gross increase in 2 months, kg		15.2 ± 3.54	16.7 ± 3.60	17.0 ± 3.62

* P≤0.05; ** P≤0.01; ***P≤0.001

Table 7 - The effect of feed additives probiotic on the incidence of sows in the early postpartum period

Indicator	Research group	№1 (control)	№2	№3
Number of sows, heads		10	10	10
Number of sick sows				
Heads		2	1	1
%		20.0	10.0	10.0
Sick with metritis-mastitis-agalactia				
Heads		1	-	1
%		50.0	-	100.0
Sick with postpartum endometritis				
Heads		1	1	-
%		50.0	100.0	-

* P≤0.05; ** P≤0.01; ***P≤0.001

Table 8 - The impact of feeding feed additive the probiotic sows during 30 days after farrowing on growth and survival of piglets

Indicator	Research group	№1 (control)	№2	№3
Number of piglets, heads		104	108	107
The average live weight of piglets, kg	At birth	1.23 ± 1.081	1.26 ± 1.073	1.26 ± 1.078
	In 2 months	16.4 ± 3.63	17.2 ± 3.63	17.3 ± 3.66
Mortality of piglets up to 2 months	heads	12	9	7
	%	11.54	8.33	6.54
Weaned piglets per sow, heads		9.2 ± 2.83	9.9 ± 2.87	10.0 ± 2.90
Average daily increase in piglets from birth to 2 months, kg		0.25 ± 0.490	0.27 ± 0.499	0.27 ± 0.502
Gross increase in 2 months, kg		15.2 ± 1.52	16.0 ± 2.31	16.0 ± 2.10

* P≤0.05; ** P≤0.01; ***P≤0.001

Among the sows in the control group, one animal (50.0%) was detected with metritis-mastitis-agalactia and postpartum endometritis. In experimental groups' No. 2 and 3, one sow each was detected with endometritis (100.0%) and metritis-mastitis-agalactia (100.0%), respectively. The effectiveness of administering the probiotic supplement to sows within 30 days from the moment of farrowing on their performance indicators was studied (Table 8). The supplementary feeding of the probiotic feed additive for one month, starting from the moment of farrowing, at inclusion rates of 1.0% and 1.5%, positively affected the growth and survival of the resulting litter.

Pigs of experimental groups No. 2 and 3 exceeded the control group in live weight at birth by 2.44%. At 2 months of age, these pigs exceeded their counterparts from the control group in this indicator by 4.88% and 5.49%, respectively. The average daily gain of piglets in research groups No. 2 and 3 from birth to 2 months increased by 5.14% and 5.53% compared to the control. The gross increase in the live weight of piglets at 2 months in research groups' No. 2 and 3 increased compared to the control by 5.08% and 5.74%, respectively. The number of weaned piglets per sow, when fed the probiotic feed additive in experimental groups No. 2 and 3, increased by 7.61% and 8.70%, respectively, compared to the control. Additionally, piglets under two months of age in the second and third groups exhibited lower mortality rates (by 3.21% and 5.0%, respectively) compared to the control group.

While assessing the intensity of piglet growth by changes in live weight is important, it does not provide a complete picture of their overall development. According to numerous studies (Van Steenberg, 1989; Alimzhanova et al., 2018; Polupan et al., 2024), evaluating animals based on their exterior is a method to determine their advantages and disadvantages, health status, physiological strength, breed characteristics, and productivity direction. Furthermore, for greater clarity on body physique features within a single breed, describing the exterior profile is useful. In this regard, at 60 days of age, basic body structure measurements were taken from piglets of all groups to determine the features of their linear growth. Piglets from experimental groups No. 2 and 3, whose mothers received different doses of the probiotic feed additive, showed an increase in all measured indicators compared to their peers in the control group. Notably, a significant difference in height at the withers was observed in experimental group No. 2 (*P≤0.05) and No. 3 (P≤0.01), and in chest girth in groups No. 2 and 3 (P≤0.001; Table 9).

Table 9 - The impact of feeding the fodder supplement of the probiotic sows for 30 days after farrowing on the arms of the body of piglets at the age of 2 months, cm

Indicator	Research group	№1 (control)	№2	№3
Height in the withers		45.1 ± 0.79	47.3 ± 0.47*	48.1 ± 0.58**
Girth of the breast behind the shoulder blades		67.1 ± 0.29	69.8 ± 0.59***	70.4 ± 0.67***
Breast width behind the shoulder blades		14.6 ± 0.36	14.7 ± 0.27	15.3 ± 0.27
Breast depth		24.2 ± 0.34	24.0 ± 0.39	24.9 ± 0.38
The length of the trunk		67.9 ± 1.56	70.5 ± 1.54	71.5 ± 1.37

* P≤0.05; ** P≤0.01; ***P≤0.001

In general, all results corresponded to the phenotypic evaluation of the breed and its production orientation - the meat type. Regarding height at the withers, chest girth behind the shoulder blades, chest width, and body length of piglets in experimental group No. 2 (from sows fed 1.0% probiotic feed additive for 30 days post-farrowing) exceeded those in the control group by 4.89%, 4.02%, 0.68%, and 3.83%, respectively.

Measurements of piglets in experimental group No. 3 (from sows fed 1.5% probiotic for 30 days post-farrowing) were also higher than the control group: height at the withers (6.65%), chest circumference behind the shoulder blades (4.92%), chest width behind the shoulder blades (4.79%), chest depth (2.89%), and body length (5.30%). However, results regarding chest depth were inconsistent. In experimental group No. 2, piglets were slightly behind their peers in the control group by 0.83%, showing a volume deficiency of only 0.2 cm. In contrast, animals in experimental group No. 3 showed a slight positive tendency, performing 2.89% better than the control. Additionally, a slight difference was noted in the piglets of the experimental groups compared with the control in chest width behind the shoulder blades: 0.68% for group No. 2 and 4.79% for group No. 3. These data, which describe the body characteristics of the piglets, are illustrated in the constructed exterior profile (Figure 2). The external forms of piglets in groups' No. 2 and 3 were visibly more developed than those of their peers in the control group. Analyzing these results, we conclude that the development of the piglets followed standard ontogenic patterns. It is characteristic of the meat (bacon) pig type that chest girth is smaller than trunk length, the trunk is elongated, the chest depth is reduced, and the anterior torso is lighter than the massive hindquarters.

The most objective judgments regarding body structure can be made by evaluating body indices (Table 10). The long-legged index reflects the relative development of the limbs and is used to characterize the body type and assess the developmental degree of animals within the same breed. In this study, pigs in experimental groups' No. 2 and 3 did not differ from each other (0.82%), but they exceeded peers in the control group by 3.95% and 3.1%, respectively. The relative length of the animal (compared to height at the withers) characterizes the stretch index.

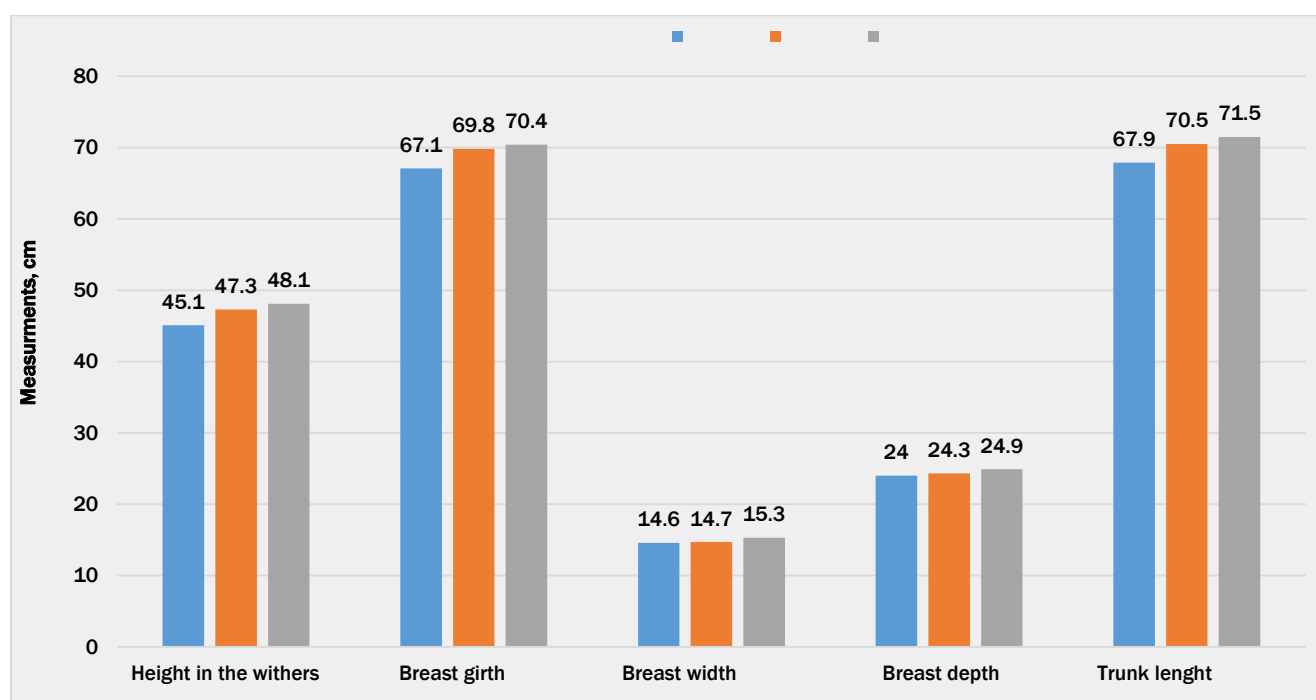
**Figure 2 - Exterior piglets profile at the age of 2 months.**

Table 10 - Pigerous body indices of piglets at the age of 2 months

Indicator	Research group	N ₁ (control)	N ₂	N ₃
Long-legged		46.78 ± 0.27	48.63 ± 0.38	48.23 ± 0.44
Stretch		150.55 ± 1.18	149.05 ± 0.98	148.65 ± 1.13
Thoracic		60.83 ± 0.95	60.49 ± 0.74	61.45 ± 0.93
Body compactness index		98.82 ± 1.21	99.01 ± 1.14	98.46 ± 1.57
Massiveness		148.78 ± 1.11	147.57 ± 0.88	146.36 ± 1.41

* P≤0.05; ** P≤0.01; ***P≤0.001

For the control group. This index was 150.55%, while in groups' No. 2 and 3 it was 149.05% and 148.65%, respectively. Animals in experimental groups' No. 2 and No. 3 showed a significant decrease in the stretch index compared with the control by 1.0% and 1.26%, respectively. The thoracic index is of greatest interest for adult animals as it serves to determine the chest ratio. Research results recorded an increase in this index in experimental group No. 3 compared with the control by 1.02%, whereas in group No. 2 this indicator was 0.66% lower than the control. The body compactness index evaluates the relative development of body mass expressed as the ratio of chest girth to trunk length. This index was 98.82% in the control group, 99.01% in group No. 2, and 98.46% in group No. 3. In general, piglets in the experimental groups' No. 2 and No. 3 exceeded the control by 0.19% and 0.36%, respectively. Finally, the massiveness index, defined as the ratio of chest girth to height at the withers, indicates the relative development of the torso. Analysis of this index suggests that piglets from sows fed 1.0% and 1.5% probiotic additives post-farrowing showed a decrease in massiveness compared with the control group by 0.81% and 1.63%, respectively.

DISCUSSION

According to scientists, probiotics are biotechnological products, or "live" active ingredients, used as food additives that consist of living microorganisms. They exert beneficial effects on host physiological functions by improving intestinal microbial equilibrium (Fuller, 1989; Kritas, et al., 2006; Anee, et al., 2021)

Gu et al., (2019) investigated the effects of isomaltooligosaccharide (IMO) and *Bacillus* on sow productivity, serum metabolites, and placental antioxidant capacity. Their findings indicated that IMO and *Bacillus* supplementation improved protein metabolism. Furthermore, the increase in dietary components led to a higher concentration of growth hormone in the serum of the umbilical cord vein, resulting in an increased birth weight of piglets. These microorganisms also play a crucial role in regulating sow health by selectively promoting the growth and metabolic functions of one or more types of bacteria in the colon. (Roberfroid, 1999).

The use of a multi-strain probiotic in pregnant sows, as demonstrated by Pereira et al. (2024) proved to be a beneficial feeding strategy to improve their welfare. Sows fed probiotic supplements exhibited better human-animal interactions and experienced reduced stress levels. Probiotic supplementation lowered cortisol levels and increased serotonin levels in sows. Furthermore, pigs born from sows fed probiotic additives tended to show reduced indicators of negative microflora during bacteriological testing.

The positive effect of a combined probiotic feed additive is also supported by Tang et al. (2024) in their research on preventing stress in pigs. Their study found that probiotics had a significant anti-stress effect. In both weaned piglets and pregnant sows receiving a combination probiotic consisting of *Lactobacillus plantarum*, *Lactobacillus reuteri*, and *Bifidobacterium longum*, changes in fecal microbiota composition were observed, influencing the piglet group.

In addition, feeding probiotic additives positively impacts sperm quality. Helli et al. (2022) reported that oral administration of probiotics can help combat oxidative damage of sperm. Probiotic additives contribute to a significant increase in semen volume, quantity, concentration and motility, as well as an increase in the overall antioxidative capacity of plasma, while significantly decreasing plasma malondialdehyde concentrations and inflammatory markers.

Research by Ngo et al. (2023) found that probiotics containing *B. amyloliquefaciens* TOA5001 improved intestinal morphology, intestinal microflora, oxidative activity (biological antioxidant potential) and sperm quality in male broiler-bidders. The findings of Sanchez-Rodriguez et al. (2024) in male mice indicated a higher percentage of normal sperm with fewer anomalies in mice that received probiotics. This suggests that, on one hand, probiotics reach the intestine, and through their metabolism microorganisms produce proteins, amino acids, and short-chain fatty acids such as propionate, acetate, and butyrate, which maintain intestinal integrity and reduce intestinal inflammation.

The use of probiotic mixture "Sviteco-PWC" in poultry significantly reduced the amount of *Eimeria aservulina* in the intestine of broilers. It also modulated intestinal microbiota composition and reduced colonization by pathogenic bacteria, thereby enhancing intestinal immunity. This led to an increase in intestinal immunity in broilers and improved production indicators (Luhovyi et al., 2025).

The impact of probiotics extends beyond the intestine and reproductive capacity. They can reach other organs and systems, leading to their use in treatment of various diseases, including heart disease and cardiovascular system disorder (Oniszczuk et al., 2021). Probiotic substances are involved in regulating the host's lipid metabolism and are utilized in managing hyperlipidemia (Jia et al., 2021), diabetes, and are particularly recommended for preventing associated joint diseases linked to insulin deficiency (Wang et al., 2022). Furthermore, probiotic intervention can mitigate hypertension, regulate intestinal flora to increase beneficial bacteria and modulate metabolites of intestinal microbial flora, such as trimethyl trimethylamine oxide, short-chain fatty acids, and polyphenols, which contribute to reducing blood pressure (Yuan et al., 2023).

CONCLUSION

The results of the study indicate the high efficiency of using probiotic feed additives in feeding sows of all ages and physiological conditions. Supplementing the diet of both young and adult sows during preparation for fertilization, before and after farrowing, had a positive effect on their reproductive performance, including increased estrus, fertilization rates, litter size, and the number of live piglets at birth. Improvements were also observed in growth rate, live weight, and piglet survival up to two months of age. Under the conditions of this study, inclusion levels of 1.0% for young sows and 1.5% for adult sows were associated with the most pronounced productive responses. Statistically significant improvements in the exterior performance of piglets were demonstrated indicating a broadly positive impact of the probiotic additive on the development of young animals. The findings substantiate the feasibility of adding probiotic supplements into technological schemes for sow feeding to enhance their productivity and improve product quality.

DECLARATIONS

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Authors' contribution

The first four authors should be considered as first authors, S. Kramarenko planned, designed, and spell-checked and supervised this study. I. Liuta collected data and samples, performed laboratory studies, analyzed and visualized the data. O. Karatieieva described the results, formulated the initial version of the manuscript and critically edited the final version of the manuscript. A. Kramarenko also managed the data and reviewed the manuscript. All authors read and approved the submitted version of the manuscript.

Ethical approval:

All animal handling procedures were conducted in accordance with European legislation (European Union Council Directive No. 98/58/EC, 1998; Nalon and Stevenson, 2019). The study protocol, evaluating the effects of the probiotic supplement on the reproductive performance of sows and the growth of piglets, was approved by the local Bioethics Committee of Mykolaiv National Agrarian University, Ukraine, adhering to Good Clinical Practice (GCP) guidelines for the protection of humane treatment of experimental animals. The entire experimental process was carried out in accordance with animal welfare regulations under the supervision of the ethics team of the Mykolaiv National Agrarian University No. 27 dated 05.06.2025.

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Competing Interests

The authors did not declare any competing interests.

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