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 THE USE OF TRADITIONAL AND INTRA-UTERINE METHODS OF ARTIFICIAL INSEMINATION OF SOWS IN INDUSTRIAL PRODUCTION CONDITIONS

Igor MOISEI[1], Mykola POVOD[1], Anna LYKHACH[2], Oleksandr MYKHALKO[1], Tetyana VERBELCHUK[3*], Valeriy BORSHCHENKO[3], Vira KOBERNIUK[3**], Kostyantyn KALITAEV[2], Kateryna YURIEVA[1], Oleksandr BAZURIN[1], Yana BORSUK[1]**

[1]Sumy National Agrarian University, Department of Feed Technology and Animal Feeding, 160, H. Kondratiiev St., Sumy, Ukraine, Phones: +38(066)0913555, +38(050)9473708, +38(066)2871386, +380665778027, E-mails: Straus22051979@gmail.com, nic.pov@ukr.net, snau.cz@ukr.net, velandra@ukr.net, fiolental@gmail.com, CivDef@ukr.net
[2]National University of Life and Environmental Sciences of Ukraine, Department of Animal Biology, 03041, 15 Heroiv Oborony Str., Kyiv, Ukraine, Phones: +30681795857, E-mails: avlykhach@nubip.edu.ua, kalitaev.k@nubip.edu.ua
[3]Polissia National University, [*]Department of Technology of Processing and Quality of Livestock Products, [**]Department of feeding, breeding of animals and preservation of biodiversity, Staryi Boulevard, 7, Zhytomyr, Ukraine, Phones: +38(098)2482590, +380671697709, +380671697709, E-mail: verba5551@ukr.net, borshenko_valery@ukr.net, kobernukvera@gmail.com

Corresponding author: snau.cz@ukr.net

Abstract

The paper aimed to assess the economic efficiency in sows reproduction using artificial insemination in industrial production conditions. For this purpose, the post-cervical method was used to inseminate the sows, and this proved to be the most efficient method compared to other insemination methods. The results showed a tendency to increase the farrowing rate by 0.68% in sows in which semen was introduced by the post-cervical method. There was also a tendency to increase the total number of piglets born in sows using the intravaginal insemination method. At the same time, no difference in multiparity was found between sows inseminated with different methods. It was found that due to the improvement of artificial insemination techniques and the introduction of the post-cervical method, the number of doses of semen required to inseminate a sow per year decreased by -13.0%, the volume of a dose of semen decreased by 44.4% and the total amount of semen decreased by 51.7%. The total amount of semen used to inseminate a sow per year decreased by 7, which proportionally reduced the cost of inseminating the entire breeding herd, the amount and cost of semen diluent, main catheters and semen disinfectant used decreased by 13.0% and the number of boars decreased by 44.0.

Key words**:** *pig farming economics, artificial insemination, post-cervical method, resource saving, sow productivity*

INTRODUCTION

Today, the efficiency and profitability of industrial pork production, as asserted by [4, 12, 35] there are closely linked to the use of artificial insemination of sows.

According to [8, 13, 14, 25, 35] the procedure depends on the quantity and location of sperm deposition in the female reproductive tract. The traditional artificial insemination method was the first to be developed and remains the simplest to implement. It was reported [2, 3, 25, 27] that this method involves depositing 2.5–3 billion sperm cells in 80–100 ml of diluted semen into the cranio-cervical region of the cervix using a simple disposable catheter to a depth of 13–15 cm. As a result, only a small proportion of sperm reaches the sow's oviducts.

According to [6, 32, 38], effective fertilization outcomes require the introduction of at least 1 billion sperm per insemination, while [1] state that optimal results under production conditions are achieved with 2.5 billion sperm. As artificial insemination technology has advanced, producers increasingly aim to achieve high sow fertility while reducing the amount of sperm used per insemination.

According to [26], research into improving this technology began in Europe more than 15 years ago. Efforts have gradually reduced the number of sperm used in conventional artificial insemination, allowing more high-quality boars to be used and improving economic efficiency in pork production. It was the reported [7] that the use of intrauterine insemination and its economic advantages, but due to technical challenges, as noted [38], it was only adopted in production at the end of the 20th century. This technique involves using a transcervical catheter to deposit semen into the cranio-cervical region of the uterus or the proximal end of its horns.

The complexity of this method, as noted by [25, 38] arises from the difficulty of navigating the catheter through the cervical mucosal folds. In contrast, traditional artificial insemination deposits semen in the sow's cervix, requiring sperm, as noted [7], 5 minutes to 3 hours to reach the uterine horns. According papers [10, 25], the duration of this process depends on sperm motility, uterine contractions, and the presence of leukocytes. It was [18, 24] reported that leukocytes cleanse and prepare the uterine surface for embryo implantation and remove excess sperm.

At published paper [11, 19, 28, 36] was noted that leukocytes appear on the uterine mucosa within 30 minutes of insemination, with their numbers sharply increasing after 2–3 hours. During this time, uterine contractions occur under the influence of oxytocin, oestrogen, and prostaglandins, as reported by [20, 25, 32]. These contractions are essential for successful sperm penetration into the oviduct. It was suggested [20] that physical contact with a boar, mechanical massage of the sow's back and sides, and stimulation of her genitalia can accelerate this process. However, excessive uterine contractions, as [20, 23, 34] observed, may reduce fertility by increasing insemination time or the frequency of semen reflux.

In addition, a decrease in sperm concentration increases the risk of reflux - the backward flow of sperm, which can lead to losses of up to 35% of the administered dose [28, 33]. It was noted [32] that reflux could cause up to 35% of semen loss, particularly problematic with low sperm concentrations. The degree of reflux depends on the sow's reproductive cycle and the volume and density of semen used [29, 32, 39].

Post-cervical insemination requires 1 billion sperm, compared to 3 billion for cervical insemination, which [5, 31, 38] believe results in better sow fertility. It was recommend using 1–1.5 billion sperm in 45–50 ml of diluted semen for post-cervical insemination [8, 22]. Studies [3, 38] reported good fertility and high prolificacy with 1 billion sperm using post-cervical insemination compared to 3 billion with vaginal insemination.

However it was reported significant fertility reduction when using 1 billion sperm under production conditions [13, 28, 38].

The introduction of artificial insemination has significantly reduced the time needed for both estrus detection and sow insemination compared to natural mating [30]. Research indicates that natural mating requires approximately 22 minutes per sow for detecting estrus and mating, whereas artificial insemination reduces this process to 1–2 minutes for estrus detection and an additional 4–5 minutes for insemination per sow [37]. Increased boar utilization efficiency and improved economic reproduction performance with stable fertility and prolificacy results when using post-cervical insemination [2, 14, 15, 25].

However, the literature contains many contradictions regarding the effectiveness of various insemination methods with reduced sperm doses and their impact on the economic performance of pork production technology. Therefore, our study aims to investigate the economic consequences of traditional (cervical) and intrauterine (post-cervical) sow insemination methods under industrial conditions in the steppe zone of Ukraine.

The purpose of the research is the effectiveness of traditional and intrauterine insemination of pigs, with the cervical and postcervical method of insemination of sows. The impact of this method of insemination on their fertility, the percentage of farrowings and the size of the litter. Also, it was comparatively evaluated the time spent on these two methods of insemination and their economic feasibility.

MATERIALS AND METHODS

To compare the conventional and postcervical methods of insemination on the commercial gearbox number 1 in the city of Globino during 2022 in accordance with the methodological recommendations [17], each weekly group of half-breed sows of the Large White Landrace breed, which consisted of 256-260 heads, was randomly divided into two parts. According to the research scheme presented in Table 1.

Table 1. Research scheme

Indicator	Group of animals	
	I Group	II Group
Insemination method	traditional insemination	postcervical insemination
Number of sows in the experiment, head	7,300	7,300
Duration of the experiment, days	300	300
Time of inseminations, times	200	200

Source: own calculations.

During the placement of sows in the insemination unit every Thursday, all sows, immediately after weaning piglets, were placed in individual crates, where they were divided into two groups by marking them with spray numbers. Odd numbers were assigned to Group I (control), and even numbers to Group II (experimental). The first group of sows was inseminated using the traditional (cervical) method, while the second group was inseminated using the post-cervical method.

Detection of estrus in sows of both groups began on the Sunday of the current week after piglet weaning and was conducted once a day at 8:00 AM in the presence of a teaser boar, which was kept in the feeding aisle in front of the sows. Insemination was performed using mixed semen from boars of the synthetic line PIC-337. For cervical insemination, the semen dose consisted of 90 ml containing 2.5 billion spermatozoa, whereas post-cervical insemination required 50 ml with 1.5 billion spermatozoa. The semen extender used was Prymxcell Ultra at a ratio of 200 g per 5 liters of distilled water.

Traditional insemination of sows commenced immediately after the immobility reflex was observed in the presence of teaser boars and was repeated after 24 hours. The semen was absorbed into the uterus naturally due to its contractions. During insemination, mechanical stimulation of the sow was performed by pressing on its back and nudging its groin area. For insemination, catheters from Magapor, packaging for semen storage from Minitub, and equipment for semen analysis and packaging from IMV were used.

Post-cervical insemination began half an hour after the immobility reflex was observed in sows. Initially, a traditional Magapor catheter was inserted into the external part of the cervix for six sows simultaneously. Next, a flexible internal catheter was inserted through the conventional catheter into the sow's uterus. After the internal catheter was fully in place, it was attached to a semen package, and the semen was released into the uterus. The catheter was then removed.

Every third week, video recordings of both traditional and intrauterine insemination processes were made using surveillance cameras. These recordings were later analyzed by qualified specialists monitoring work processes. The preparation time for semen, the handling of boars, and the insemination of sows were recorded. Timing began when the operator brought the boar between the rows of sows. For the traditional insemination group, timing ended when the last sow finished absorbing the semen and the final catheter was removed. For the post-cervical insemination group, timing ended when the semen was fully expelled into the uterus of the last sow, and both catheters were removed. After data processing, the total insemination time for each sow was determined.

When entering sow insemination data into the recording system, a note was added regarding the insemination method. Using this data, the insemination rate was calculated as the proportion of sows confirmed pregnant via ultrasound to the total number of sows inseminated. The farrowing rate was determined by dividing the number of sows that farrowed by the total number of inseminated sows. After farrowing, the total number of piglets born and the number of viable piglets per farrowing were calculated. These

calculations were performed according to the biometric data analysis recommendations [16]. Based on the annual report on the use of different sow insemination methods, the economic efficiency of various insemination methods across the farm, with a population of 15,510 productive sows, was calculated using the methodology [17].

RESULTS AND DISCUSSIONS

As can be seen from Table 2, the same number of sows was taken in each group in the study. According to the results of ultrasound scanning of sows on the 35th day after insemination, no difference was found in the fertility rate of sows.

Table 2. Fertility and fecundity of sows using cervical and postcervical methods of artificial insemination

Indicator	Group of animals	
	I Group	II Group
Average number of sows in the group, head	258.9	255.5
Fertility rate, total,%	96.61±0.11	96.65±0.17
Farrowing rate, %	94.14±0.09	94.82±0.16
Total number of piglets born, head	16.11±0.17	16.33±0.24
Multiparity, head	15.11±0.15	15.10±0.21

Source: own calculations.

No notable differences were found in the farrowing rates of sows between the various insemination methods, though a slight trend indicated a 0.68% increase in farrowing rate for sows inseminated using the post-cervical method. Furthermore, a trend was observed suggesting an increase in the total number of piglets born to sows inseminated via the intrauterine method. However, no differences in prolificacy were noted between sows inseminated by the different methods.

To determine the annual economic efficiency of the cervical and post-cervical artificial insemination methods, a comparative analysis of these two approaches was conducted for the productive sow herd at LLC NVP Globinsky Pig Compleks. As shown in Table 3, due to a lower number of inseminations per sow, 0.75 fewer semen doses (13.0% less) were used for post-cervical insemination compared to the traditional method. Additionally, the volume of semen doses for post-cervical insemination was 40 ml (44.4%) lower than for the traditional method due to changes in the semen delivery location. As a result of these two factors, the total annual semen volume per sow was 519 ml for cervical insemination, compared to only 251 ml for post-cervical insemination - a difference of over twice as much (268 ml).

Considering that the cost of maintaining boars is the same for both methods, the cost per semen dose, due to its smaller volume, was 0.93 EUR (55.7%) lower for intrauterine insemination compared to the traditional method.

Table 3. Sperm quantity for insemination of sows by different methods

Indicators	Insemination method	
	Cervical	Postcervical
Average annual number of sows in the farm (heads)	15,510.0	15,510.0
Number of sperm doses per year, taking into account 20% of the void with double insemination	5.77	5.02
Volume of one sperm dose (ml)	90.0	50.0
Volume of sperm per 1 sow per year (ml)	519.3	251.0
Cost of one sperm dose (Euro)	1.68	0.74
Annual number of sperm doses for the entire livestock (ml)	89,493.0	77,860.0
Annual cost of sperm, for the entire livestock (Euro)	150,609.6	58,110.1

Source: own calculations.

The annual number of semen doses for the entire herd using intrauterine insemination amounted to 77,860, which is 11,632.5 doses or 13.0% less compared to the traditional insemination method. Overall, considering the differing semen dose volumes, the total cost of semen for intrauterine insemination over the year was 59,563.05 EUR, which is 94,811.85 EUR or 61.4% less than the cost for traditional insemination.

Due to the smaller number of semen doses, less semen diluent was used for intrauterine insemination compared to the traditional method. As shown in Table 4, 7,007.4 liters of

diluent were used for intrauterine insemination annually, which is 1,046.925 liters or 13.0% less than the amount used for traditional insemination.

With the price per liter of diluent being the same for both methods, the cost of diluent for traditional insemination was €1,965.08 higher, totaling 15,118.00 EUR.

The lower number of inseminations with the post-cervical method also required fewer primary catheters. The number of primary catheters used for post-cervical insemination was 77,860, which is 11,633 fewer than for traditional insemination. Consequently, the cost of primary catheters was 2,413.74 EUR lower for intrauterine insemination compared to the cervical method.

However, intrauterine insemination requires the addition of intrauterine catheters, amounting to 77,860 units at a cost of 29,197.58 EUR. Therefore, despite the lower number of primary catheters, the total cost of all catheters was 26,783.83 EUR higher for post-cervical insemination compared to traditional insemination, amounting to 45,353.58 EUR.

Table 4. Quantity and cost of inventory and additional ingredients for insemination of sows by various methods

Indicators	Insemination method	
	Cervical	Postcervical
Amount of diluent per year (l)	8,054.3	7,007.4
Cost of diluent per year (EUR)	14,749.3	12,832.1
Number of main catheters (pcs)	89,493	77,860
Cost of main catheters (EUR)	14,749.3	12,832.1
Number of intrauterine catheters (pcs)	742,789	646,240
Cost of intrauterine catheters (EUR)	0.0	28,485.4
Total cost of catheters (EUR)	18,116.8	44,247.4
Disinfectant for sperm, l	1,342.4	1,167.9
Annual cost of disinfectant (EUR)	26,193.0	22,788.4
Annual cost of additional insemination aids (EUR)	1,347,509.5	2,340,259.6

Source: own calculations.

Due to the smaller overall volume of semen used in the intrauterine insemination method, 174.5 liters less disinfectant was required, totalling 1,167.9 liters for this method. Since the market price per liter of disinfectant is the same for both insemination methods, the annual cost of disinfectant for the post-cervical method amounted to 23,358.06 EUR, which is 24,818.75 EUR less compared to the traditional insemination method. Considering the reduced amount of semen required to inseminate 15,510 sows using the post-cervical method, it becomes possible to decrease the number of breeding boars kept (Table 5).

For the traditional insemination method, inseminating 15,510 sows requires maintaining 103 boars, whereas intrauterine insemination reduces this number by 44.0% to 58 boars. Accordingly, the costs of purchasing these animals and their maintenance are also reduced. At a price of 2,812.5 EUR per high-index breeding boar and an average usage period of 0.7 years, the annual depreciation cost per boar for both methods is 4,017.86 EUR. Considering the larger number of boars required for inseminating all sows using the traditional method, the annual depreciation cost for this method amounts to 415,446.43 EUR, while for the post-cervical insemination method, it is 182,796.43 EUR lower.

Given the same annual maintenance cost of 4,017.86 EUR per boar for both insemination methods, the total maintenance cost for all boars required for inseminating 15,510 sows using the cervical method amounts to 415,446.43 EUR.

In contrast, for the post-cervical method, this cost is 182,796.43 EUR lower, amounting to 232,650.0 EUR.

Considering the need for skilled labor by insemination technicians for both methods, the time spent by a technician to inseminate one sow is a critical factor. Time measurements were conducted for both methods, revealing that traditional insemination, due to the need for massaging the sow and waiting for sperm

absorption, requires 7.5 minutes per sow. In contrast, post-cervical insemination, which eliminates the need for massaging and allows for forced sperm introduction into the uterus, reduces this time by 4.3 minutes or 57.3%, to 3.2 minutes.

Table 5. Depreciation cost and cost of keeping boars for insemination of sows by various methods

Indicators	Insemination method	
	Cervical	Postcervical
Number of breeding boars (heads)	103	58
Annual cost of keeping one boar (EUR)	224.7	224.7
Cost of keeping boars (EUR)	23,237.3	13,012.9
Purchase cost of one boar (EUR)	2,743.9	2,743.9
Average duration of use of a boar (years)	0.5	0.5
Annual depreciation cost of one boar (EUR)	5,487.8	5,487.8
Annual depreciation cost of all boars (EUR)	567,439.0	317,765.9
Insemination time of 1 sow (minutes)	7.5	3.2
Total time costs of artificial insemination technicians (hours)	11,186.5875	4,152.544
Cost of an hour of work of the operator and artificial insemination technician, (EUR)	2.5	2.5
Annual cost of work of the operator and artificial insemination technician (EUR)	28,212.0	10,472.5
Total costs of insemination of all sows (EUR)	828,557.0	479,229.4
Cost of insemination of one sow (EUR)	53.4	30.9

Source: own calculations own calculations.

For inseminating 15,510 sows, the traditional method requires 11,186.6 hours of labor annually, while the post-cervical method reduces this time by 7,034 hours or 62.9%, requiring only 4,152.5 hours. At a labor cost of 2.59 EUR per hour at LLC NVP Globinsky Pig Complex, the annual labor cost for the traditional method is 28,917.33 EUR, while for the post-cervical method, it is 18,183.0 EUR lower, amounting to 10,734.33 EUR.

Summarizing the overall costs for inseminating 15,510 sows, the traditional method totals 683,092.4 EUR, whereas the post-cervical method reduces these costs by 284,942.28 EUR, amounting to 398,150.11 EUR. The annual cost per sow for the traditional method is 44.04 EUR, while for the post-cervical method, it is 41.7% or 18.38 EUR lower, amounting to 25.67 EUR.

Therefore, the advancement of artificial insemination techniques and the adoption of the post-cervical method resulted in a 13.0% decrease in the number of semen doses needed per sow each year, a 44.4% reduction in the volume of each semen dose, and a 51.7% reduction in the total semen quantity required per sow annually. This contributed to a 61.4% decrease in semen costs for the entire sow herd. The introduction of the intrauterine insemination method also reduced the use of semen diluents and disinfectants by 13.0%, the number of boars required for sow herd insemination by 44.0%, and the corresponding depreciation and maintenance costs, while lowering insemination labor costs by 62.9%.

The increased use of intrauterine catheters led to a 144.2% rise in their total cost, slightly raising the overall expense of the intrauterine insemination process, the post-cervical method still resulted in an 18.38 EUR or 41.7% reduction in the annual insemination cost per sow compared to the traditional method. For the total of 15,510 sows, this represents a savings of 284,942.28 EUR.

Our findings, which show a 0.68% increase in the farrowing rate in sows inseminated using the post-cervical method, are consistent with the results of [5, 31, 38], but contrast with the research of [33], which indicated a trend toward a higher farrowing rate and larger litter size with the traditional insemination method. Our research findings also coincided with [21] regarding the increase in farrowing rates and the total number of piglets born with intrauterine insemination, but did not align with his results regarding an increase in sow prolificacy with this method, as no difference

in prolificacy was observed in our study when comparing the two insemination methods.

The results of our study regarding the significant reduction in time for post-cervical insemination of sows compared to traditional insemination agree with the conclusions of [8, 9, 33], but do not match in quantitative terms, which, in our opinion, is due to differences in the qualifications of the insemination technicians.

Our conclusions regarding the higher economic efficiency of the post-cervical insemination method compared to the traditional method were similar to the reports [2, 14, 15, 25], which mention the improved efficiency in the use of boars and increased labor efficiency of artificial insemination technicians.

CONCLUSIONS

A tendency towards an increase in the farrowing rate and an increase in the total number of piglets born in sows to which sperm was introduced using the post cervical method was established. At the same time, no difference in multiparity between sows inseminated by different methods was established.

With the post-cervical method of artificial insemination, the number of sperm doses required for insemination of one sow per year decreased by 13.0%, the volume of one sperm dose decreased by 44.4%, and the total amount of sperm decreased by 51.7%, as did the quantity and cost of sperm diluent used, the central catheters for insemination of one sow per year.

It was established that with intrauterine insemination, the working time of artificial insemination operators decreased by 57.3% for the insemination of one sow, and the total cost of their labor and payment decreased by 62.9%.

Intrauterine insemination reduces the number of boars, their depreciation costs, and maintenance expenses by 44.0%, resulting in a more efficient utilization of their highly productive capacity. The post-cervical insemination method cuts the cost of inseminating a sow by 41.7% compared to the traditional method. The post-cervical insemination method allows to reduce the cost of insemination of one sow by 41.7% compared to the traditional method of insemination.

REFERENCES

[1]Alm, K., Peltoniemi, O. A., Koskinen, E., Andersson, M., 2006, Porcine field fertility with two different insemination doses and the effect of sperm morphology. Reproduction in Domestic Animals, Vol. 41(3): 210–213. https://doi.org/10.1111/j.1439-0531.2005.00670.x

[2]Belstr, B., Ter Bik, V., 2024, Porivniannia riznykh metodiv shtuchnoho osimeninnia svynomatky [Comparison of different methods of artificial insemination of sows]. [in Ukrainian]. https://pigua.info/uk/post/Porivnyannya-riznykh-metodiv-shtuchnoho-osimeninnya-svynomatky, Accessed on 3 January 2025.

[3]Belstra, B. A., Willenburg, K. L., Gómez-López, D. H., Knox, R. V., Stewart, K. R., 2020, Effects of the number of sperm and site of uterine semen deposition on conception rate and the number of embryos in weaned sows receiving a single fixed-time insemination. Journal of Animal Science, Vol. 98(9): p.skaa260. https://doi.org/10.1093/jas/skaa260

[4]Brassley, P., 2007, Cutting across nature? The history of artificial insemination in pigs in the United Kingdom. Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences, Vol. 38(2): 442–461. https://doi.org/10.1016/j.shpsc.2007.03.008

[5]Cassar, G., Kirkwood, R. N., Poljak, Z., Bennett-Steward, K., Friendship, R. M., 2005, Effect of single or double insemination on fertility of sows bred at an induced estrus and ovulation. Journal of Swine Health and Production, Vol. 13: 254–258. https://www.researchgate.net/publication/242465422_Effect_of_single_or_double_insemination_on_fertility_of_sows_bred_at_an_induced_estrus_and_ovulation Accessed on 3 January 2025.

[6]Dimitrov, S., Jeliazkov, E., Levis, D., 2007, Deep intrauterine and transcervical insemination of sows and gilts. Trakia Journal of Sciences, Vol. 5: 40–46. https://www.researchgate.net/publication/228614998_Deep_intrauterine_and_transcervical_insemination_of_sows_and_gilts Accessed on 3 January 2025.

[7]Hancock, J. L., 1959, Pig insemination technique. Veterinary Record, Vol. 71: 523–527.

[8]Hedeboe, A. M., Thorup, F., Greve, T., Jensen, H. E., 2004, Dyb insemination. Meddelelse nr. 654, Landsudvalget for Svin. [In Danish] https://svineproduktion.dk/-/media/PDF---Publikationer/Meddelelser-2019/Meddelelse_1180.pdf Accessed on 3 January 2025.

[9]Hedeboe, A. M., 2006, Dyb insemination med reduceret antal sædceller. Meddelelse no. 735, Landsudvalget for Svin. [In Danish]

https://svineproduktion.dk/publikationer/kilder/lu_med d/2008/808, Accessed on 3 January 2025.
[10]Hernández-Caravaca, I., Izquierdo-Rico, M. J., Matás, C., Carvajal, J. A., Vieira, L., Abril, D., Soriano-Úbeda, C., García-Vázquez, F. A., 2012, Reproductive performance and backflow study in cervical and post-cervical artificial insemination in sows. Animal Reproduction Science, Vol. 136(1–2): 14–22. https://doi.org/10.1016/j.anireprosci.2012.10.007
[11]Knox, R. V., Zas, S. L., 2001, Factors influencing estrus and ovulation in weaned sows as determined by transrectal ultrasound. Journal of Animal Science, Vol. 79: 2957–2963. https://doi.org/10.2527/2001.79122957x
[12]Knox, R. V., Esparza-Harris, K. C., Johnston, M. E., Webel, S. K., 2017, Effect of numbers of sperm and timing of a single, post-cervical insemination on the fertility of weaned sows treated with OvuGel®. Theriogenology, Vol. 92: 197–203. https://doi.org/10.1016/j.theriogenology.2017.01.033
[13]Knox, R. V., 2016, Artificial insemination in pigs today. Theriogenology, Vol. 85(1): 83-93. https://doi.org/10.1016/j.theriogenology.2015.07.009
[14]Kovalenko, V. F., Pylypenko, S. V., 2005, Porivniannia trokh metodiv shtuchnoho osimeninnia svynomatok [Comparison of three methods of artificial insemination of sows]. Ahrarnyi visnyk Prychornomoria [Agrarian Bulletin of the Black Sea Region], Vol. 31: 103–104. [in Ukrainian]. https://svinarstvo.com/zbirnyk/archive/66/66.pdf Accessed on 3 January 2025.
[15]Kraeling, R. R., Webel, S. K., 2015, Current strategies for reproductive management of gilts and sows in North America. Journal of Animal Science and Biotechnology, Vol. 6(1): 3. https://doi.org/10.1186/2049-1891-6-3
[16]Kramarenko, S.S., Luhovyi, S.I., Lykhach, A.V., Kramarenko, S.S., 2019, Analiz biometrychnykh danykh u rozvedenni ta selektsii tvaryn [Analysis of biometric data in animal breeding and selection: textbook]. Mykolaiv: MNAU. 211 p. [in Ukrainian]. https://dspace.mnau.edu.ua/jspui/bitstream/123456789/6208/1/Analiz%20biometrychnykh%20danykh%20u%20rozvelenni%20ta%20selektsii%20tvaryn.pdf Accessed on 3 January 2025.
[17]Ladyka, V.I., Khmelnychiy, L.M., Povod, M.G., 2023, Tekhnolohiia vyrobnytstva i pererobky produktsii tvarynnytstva: pidruchnyk dlia aspirantiv [Technology of production and processing of livestock products: a textbook for graduate students]. Odesa: Oldi+. 244 p. [in Ukrainian].
[18]Lamberson, W.R., Safranski, T.J., 2000, A model for economic comparison of swine insemination programs. Theriogenology, Vol. 54(5): 799–807. https://doi.org/10.1016/S0093-691X(00)00391-5
[19]Langendijk, P., Soede, N.M., Kemp, B., 2005, Uterine activity, sperm transport, and the role of boar stimuli around insemination in sows. Theriogenology, Vol. 63(2): 500–513. https://doi.org/10.1016/j.theriogenology.2004.09.027
[20]Langendijk, P., van den Brand, H., Soede, N.M., Kemp, B., 2000, Effect of boar contact on follicular development and on estrus expression after weaning in primiparous sows. Theriogenology, Vol. 54(8): 1295–1303. https://doi.org/10.1016/S0093-691X(00)00436-2
[21]Madsen, M.T., 2008, Dyb insemination ved anvendelse af tokammer pose. Meddelelse nr. 808, Dansk Svineproduktion. [In Danish] https://svineproduktion.dk/-/media/PDF---Publikationer/Meddelelser-2020/Meddelelse_1199.pdf Accessed on 3 January 2025.
[22]Mozo-Martín, R., Gil, L., Gómez-Rincón, C.F., Dahmani, Y., García-Tomás, M., Úbeda, J.L., Grandía, J., 2012, Use of a novel double uterine deposition artificial insemination technique using low concentrations of sperm in pigs. Veterinary Journal, Vol. 193: 251–256. https://doi.org/10.1016/j.tvjl.2011.11.007
[23]Pelland, C., Cassar, G., Kirkwood, R., Friendship, R., 2008, Fertility after intrauterine insemination with conventional or low numbers of spermatozoa in sows with synchronized ovulation. Journal of Swine Health and Production, Vol. 16: 188–192. https://www.aasv.org/shap/issues/v16n4/v16n4p188.pdf Accessed on 3 January 2025.
[24]Pursel, V.G., Johnson, L.A., 1974, Glutaraldehyde fixation of boar spermatozoa for acrosome evaluation. Theriogenology, Vol. 1(2): 63–68. https://doi.org/10.1016/0093-691X(74)90008-9
[25]Pylypenko, S.V., 2006, Fiziolohichne obgruntuvannia ta udoskonalennia vnutrishnomatkovoho osimeninnia svynei [Physiological justification and improvement of intrauterine insemination of pigs: PhD Dissertation], Poltava, 157 p. [in Ukrainian]. http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=ARD&P21DBN=ARD&Z21ID=&Image_file_name=DOC/2006/06psvvos.zip&IMAGE_FILE_DOWNLOAD=1 Accessed on 3 January 2025.
[26]Roca, J., Parrilla, I., Bolarin, A., Martinez, E.A., Rodriguez-Martinez, H., 2016, Will AI in pigs become more efficient? Theriogenology, Vol. 86(1): 187–193. https://doi.org/10.1016/j.theriogenology.2015.11.026
[27]Rodríguez-Martínez, H., Saravia, F., Wallgren, M., Tienthai, P., Johannisson, A., Vázquez, J.M., Martínez, E., Roca, J., Sanz, L., Calvete, J.J., 2005, Boar spermatozoa in the oviduct. Theriogenology, Vol. 63(2): 514–535. https://doi.org/10.1016/j.theriogenology.2004.09.028
[28]Rozeboom, K.J., Reicks, D.L., Wilson, M.E., 2004, The reproductive performance and factors affecting on-farm application of low-dose intrauterine deposit of semen in sows. Journal of Animal Science, Vol. 82: 2164–2168. https://doi.org/10.2527/2004.8272164x
[29]Sbardella, P.E., Ulguim, R.R., Fontana, D.L., Ferrari, C.V., Bernardi, M.L., Wentz, I., Bortolozzo, F.P., 2014, The post-cervical insemination does not impair the reproductive performance of primiparous sows. Reproduction in Domestic Animals, Vol. 49: 59–64. https://doi.org/10.1111/rda.12224

[30]Serret, C.G., Alvarenga, M.V.F., Cória, A.L.P., Dias, C.P., Corcini, C.D., Corrêa, M.N., Deschamps, J.C., Bianchi, I., Lucia, T. Jr., 2005, Intrauterine artificial insemination of swine with different sperm concentrations, parities, and methods for prediction of ovulation. Animal Reproduction, Vol. 2: 250–256. https://www.animal-reproduction.org/article/5b5a6089f7783717068b4802 Accessed on 3 January 2025.

[31]Shostia, A.M., Usenko, S.O., Ustenko, A.V., Skrynnyk, V.H., 2022, Shtuchne osimeninnia svynomatok malymy dozamy spermy [Artificial insemination of sows with small doses of sperm]. In: Materialy mizhnarodnoi naukovoi internet-konferentsii "Rozvytok haluzi tvarynnytstva v umovakh yevrointehratsii" [Materials of the international scientific internet conference "Development of the livestock industry in the conditions of European integration"]. Poltava, 140–142. [in Ukrainian]. https://www.svinarstvo.com/news/16_11_2022/internet-conference.pdf#page=141 Accessed on 03.01.2025

[32]Steverink, D.W., Soede, N.M., Bouwman, E.G., Kemp, B., 1997, Influence of insemination-ovulation interval and sperm cell dose on fertilization in sows. Journal of Reproduction and Fertility, Vol. 111: 165–171. https://doi.org/10.1530/jrf.0.1110165

[33]Thorup, F., Bache, J.K., 2019, Traditionel Kontra Dyb Insemination. [In Danish] https://svineproduktion.dk/publikationer/kilder/lu_medd/2019/1180 Accessed on 3 January 2025.

[34]Usenko, S.O., 2014, Osoblyvosti metodychnykh pidkhodiv do shtuchnoho osimeninnia svynei [Peculiarities of methodological approaches to artificial insemination of pigs]. Svynarstvo: mizhvidom. temat. zb. [Pig farming: interdepartmental thematic collection], Vol. 64: 105–110. [in Ukrainian]. http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?I21DBN=LINK&P21DBN=UJRN&Z21ID=&S21REF=10&S21CNR=20&S21STN=1&S21FMT=ASP_meta&C21COM=S&2_S21P03=FILA=&2_S21STR=svun_2014_64_18 Accessed on 03.01.2025

[35]Usenko, S.O., Shostia, A.M., Nevidnychyi, O.S., Tsybenko, V.H., Kirian, R.M., 2017. Suchasni metody pidvyshchennia vidtvoriuvalnoi funktsii svynei. Problemy vidtvorennia ta okhorony bioriznomanittia Ukrainy [Modern methods of increasing the reproductive function of pigs. Problems of reproduction and protection of biodiversity of Ukraine]. In: Materialy Vseukr. nauk.-prakt. konf. [Materials of the All-Ukrainian scientific-practical conference], Poltava, 75–79. [in Ukrainian]. https://dspace.pdau.edu.ua/handle/123456789/15752 Accessed on 3 January 2025.

[36]Viring, S., Einarsson, S., 1981, Rozpodil spermy v statevykh shliakhakh pryrodno zaplidnenykh svynok [Distribution of sperm in the reproductive tract of naturally inseminated sows]. Nordisk Veterinaermedicin, Vol. 33(3): 145–149.

[37]Waberski, D., Magnus, F., Mendonca Ferreira, F., Petrunkina, A.M., Weitze, K.F., Töpfer-Petersen, E., 2005, Importance of sperm-binding assays for fertility prognosis of porcine spermatozoa. Theriogenology, Vol. 63(2): 470–484. https://doi.org/10.1016/j.theriogenology.2004.09.025

[38]Watson, P.F., Behan, J.R., 2002, Intrauterine insemination of sows with reduced sperm numbers: results of a commercially based field trial. Theriogenology, Vol. 57: 1683–1693. https://www.sciencedirect.com/science/article/pii/S0093691X02006489 Accessed on 3 January 2025.

[39]Weitze, K.F., Petzoldt, R., 1992, Preservation of semen. Animal Reproduction Science, Vol. 28(1–4): 229–235. https://doi.org/10.1016/0378-4320(92)90109-Q