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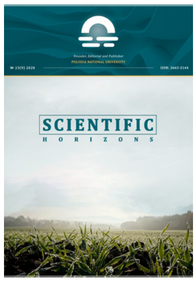

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Analysis of variability in gestation length in sows and its association with litter traits at birth

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Abstract. Gestation length is a complex polygenic trait in sows that significantly determines their productive characteristics and influences foetal development during the embryonic period. This study aimed to analyse the effects of genotypic factors (breed of the sow and sire boar) and environmental factors (year and season of farrowing) on the variability of gestation length in sows and to determine the nature of its association with litter traits at birth using a meta-analysis algorithm. The analysis was based on primary data regarding reproductive traits in the main herd of the private joint-stock company "Plemzavod "Stepnoi", Zaporizhzhia Region, collected from 2010 to 2013. The mean gestation length for the animals in the study herd was 115.9 ± 0.04 days, with a range of 110 to 121 days. Gestation length exhibited a very low level of inter-individual variability, with a coefficient of variation of only 1.65%. Duroc sows exhibited shorter gestation lengths, lower total litter sizes, and fewer live piglets per

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litter at birth compared to Landrace sows (in all cases: $P < 0.001$). A significant influence of the sire boar's breed on the reproductive traits of sows was established, except for gestation length and total litter size. The longest gestation lengths were recorded during the winter months, whereas the best performance in other reproductive traits was observed in the spring. Meta-analysis revealed that the "general" estimates of the phenotypic correlation coefficient between gestation length and total litter size, the number of live piglets, and total litter weight at birth were significant and negative. In contrast, the correlation between gestation length and the average birth weight of live piglets was significant and positive

Keywords: reproductive traits; genotypic and environmental factors; meta-analysis; pigs

INTRODUCTION

Modern pig farming increasingly focuses on improving the reproductive performance of sows and enhancing the survival of suckling piglets until weaning. However, selection aimed at increasing litter size often leads to a corresponding rise in piglet mortality rates at birth and during the suckling period. Therefore, to improve sow fertility, additional selection criteria must be developed to address the associated decline in the quality of neonatal and suckling piglets. As noted in the study by Z. Liu *et al.* (2022), gestation length is a key complex polygenic trait in sows that significantly influences their productivity and affects foetal development during the embryonic period. Gestation length is defined as the period from the last successful insemination to farrowing. In most cases, it spans approximately three months, three weeks, and three days (114-115 days) and is influenced by various factors such as the breed of the sow and sire boar, parity, year and season of farrowing. During the final days of gestation, the foetus undergoes critical organ development and weight gain. Consequently, an extended gestation period contributes to better piglet development and increased viability after birth.

The findings indicate a significant genotypic component influencing the variability of gestation length in sows. For instance, L. Shi *et al.* (2023) identified 1,002 SNPs significantly associated with gestation length during a genome-wide association study (GWAS) targeting genetic markers related to this trait. Additionally, a locus on pig chromosome 4 (ASGA0017859, SSC4, 7.8 Mb) was identified as being associated with substantial variability in gestation length across the first to fourth parities (See *et al.*, 2019). On the other hand, gestation length is also influenced by sow health. M. Parada Sarmiento *et al.* (2023) observed a tendency for reduced gestation length in animals exposed to stressors, such as laminitis. Furthermore, in crossbred animals (Large White × Landrace), conditions such as inadequate uterine involution, which can lead to postpartum disorders and negatively affect the reproductive cycle, were also linked to gestation length. M.I. Matsenko (2020) demonstrated that shortening the embryonic development period of piglets positively affects their growth rate, accompanied by improved haematological parameters, which should be considered in swine breeding programs (Egli *et al.,* 2022).

According to M. Ju *et al.* (2021), recent years have seen a gradual increase in litter size at birth in pig farming. This trend is significantly positively correlated with longer farrowing durations and gestation lengths. Additionally, a notable association was observed between gestation length and traits characterising the qualitative and quantitative properties of the litter at farrowing, possibly due to uterine capacity constraints and the length of the farrowing process. Interestingly, sows with the largest litters often exhibited the shortest gestation lengths. Furthermore, R. Bumpenkul and N. Imboonta (2021) demonstrated significant associations between gestation length and fertility traits, including total litter size, the number of live piglets, and stillbirths at birth. Overall, selection for increased litter size at birth in sows is accompanied by a tendency towards shorter gestation lengths.

Numerous findings reported by B. Medrado *et al.* (2021) demonstrate associations between gestation length and litter traits at birth. However, these results exhibit a degree of heterogeneity, as they were obtained from experimental groups of varying sizes, involving different breeds or crossbred animals, and under diverse management and feeding conditions for gestating and farrowing sows. Consequently, individual studies may either underestimate or overestimate the actual values. In such cases, meta-analysis (utilising a random-effects model) provides a means to assess the heterogeneity of individual studies and offers more reliable "general" results.

The study by D.M. Gathura *et al.* (2020) highlighted the advantages of using meta-analysis to investigate genetic parameters in beef cattle, while A.D. Hayward (2022) applied meta-analysis to explore genetic resistance to lung nematodes in sheep. In pig farming, meta-analysis has been employed to examine reproductive traits, such as the effects of oxytocin and carbetocin on farrowing characteristics and litter size, as reported by B.B.D. Muro *et al.* (2021). Similarly, R.H.R. Moreira *et al.* (2020) used meta-analysis to investigate factors affecting piglet birth weight variability. However, no comparable studies have yet been conducted on the key trait of sow gestation length and its association with litter traits at birth.

This study aimed to analyse the factors influencing sow gestation length and to establish the relationship between gestation length and litter traits at birth using meta-analysis.

MATERIALS AND METHODS

The analysis utilised primary data on the reproductive traits of sows from the main herd of the private joint-stock company "Plemzavod "Stepnoi" in the Zaporizhzhia Region. The sows belonged to the Duroc breed (DR; $n = 654$ heads) and the Landrace breed (LN; $n = 584$ heads), with an average parity of 2.25 ± 1.61 and 2.51 ± 1.70 (*Mean* ± SD), respectively, ranging from 1 to 9 parities. For each farrowing, the following traits were evaluated: gestation length (GL), total number of piglets born (TNB), number of piglets born alive (NBA), number of stillborn piglets (NSB), stillbirth rate (SBR) within the litter, total litter weight at birth (LWB), and mean piglet birth weight (MBW). Table 1 presents the descriptive statistics for the reproductive traits of the studied sows.

***Table 1**. Descriptive statistics for the reproductive traits of the studied sows (n = 2,863)*

Trait (unit of measurement)	*min*	*max*	*Mean ± SE*	*SD*	*As* ± SE_{As}	*Ex* ± SE_{Ex}
GL (days)	110	121	115.9 ± 0.04	1.92	-0.12 ± 0.05	-0.10 ± 0.09
TNB (heads)	3	21	10.06 ± 0.05	2.62	-0.05 ± 0.05	0.36 ± 0.09
NBA (heads)	1	17	8.60 ± 0.05	2.52	-0.40 ± 0.05	0.72 ± 0.09
NSB (heads)	0	15	1.46 ± 0.03	1.82	1.85 ± 0.05	4.77 ± 0.09
SBR (%)	0	100	13.7 ± 0.32	16.97	1.98 ± 0.05	5.86 ± 0.09
LWB (kg)	3.3	30.6	15,6 ± 0.08	4.27	-0.14 ± 0.05	-0.05 ± 0.09
MBW (kg)	1.0	2.0	1.803 ± 0.002	0.13	-0.72 ± 0.05	3.20 ± 0.09

Note: *min, max – minimum and maximum values; Mean ± SE – arithmetic mean and its standard error; SD – standard deviation; As ± SEAs – skewness coefficient and its standard error; Ex ± SEEx – kurtosis coefficient and its standard error*
Source: *developed by the authors*

The sows were inseminated with semen from sire boars of three breeds: Duroc (DR; $n = 38$), Landrace (LN; $n = 35$), and Large White (LW; $n = 39$). In total, data from 2,863 farrowings that occurred between 2010 and 2013 were included in the analysis. To evaluate the effects of genotypic factors (sow breed and sire boar breed) and environmental factors (year and season of farrowing) on the reproductive traits of the experimental group, the authors employed the General Linear Model (GLM) algorithm:

$$Y_{ijklm} = \mu + SB_i + BB_j + YoF_k + SoF_l + e_{ijklm}, \quad (1)$$

where Y_{ijklm} is the value of the corresponding trait for the *m*-th sow; μ is the overall mean; SB_i is the fixed factor "sow breed" with two levels (DR, LN); BB_j is the fixed factor "sire boar breed" with three levels (DR, LN, LW); YoF_k is the fixed factor "year of farrowing" with four levels (2010, 2011, 2012, 2013); SoF_l is the fixed factor "season of farrowing" with four levels: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November); e_{ijklm} is the error term.

For each subgroup (based on sow breed, sire boar breed, year, and season of farrowing), the mean values were calculated using the least squares means (LSM) method with corresponding errors (± *SE*), as well as the significance level of the influence of each factor included in the model (1). To analyse the combined effect of sow breed and sire boar breed on reproductive traits, a twofactor analysis of variance (with fixed factors) was employed. Pairwise comparisons of subgroup means were carried out using Tukey's *post-hoc* analysis (for unequal group sizes). All mathematical and statistical analyses of the data were performed using STATISTICA v.7 software. To analyse the relationship between gestation length and both qualitative and quantitative traits of the litter and individual piglets at birth, estimates of the phenotypic correlation coefficient (r) were calculated for animal groups based on sow breed. Subsequently, a meta-analysis was conducted, incorporating both the authors' own results and the estimates of the phenotypic correlation coefficient between gestation length and other reproductive traits of sows, as reported in the literature.

The literature search was conducted using the bibliographic databases PubMed and Google Scholar based on the key terms (and their combinations) "pig, swine", "sow", "reproductive traits", and "gestation length" from 2019 to 2023. A total of 101 publications meeting these criteria were analysed. Subsequently, based on the obtained values of the phenotypic correlation coefficient, a meta-analysis was performed using the online programme Meta-Mar v. 3.5.1. A test for data heterogeneity was conducted using the χ^2 test (with corresponding significance level P) and the heterogeneity index I^2. In cases where the initial data showed low heterogeneity ($I^2 \leqslant 50\%$ and $P > 0.05$), a fixed-effects model was used, whereas, for high heterogeneity in the data ($I^2 > 50\%$ and $P < 0.05$), a random-effects model was applied. The results of the meta-analysis represented the "general" estimate of the correlation coefficient and its 95% confidence interval (Borenstein *et al.*, 2021). The care and handling of the experimental animals and all related procedures were carried out by the Law of Ukraine No. 249 "On the Procedure for Carrying out Experiments and Experiments on Animals by Scientific Institutions" (2012) and the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (1986).

RESULTS AND DISCUSSION

General characteristics of the reproductive traits of sows. The average number of piglets per litter in the sows studied at the private joint-stock company "Plemzavod "Stepnoi" in the Zaporizhzhia Region from 2010 to 2013 was 10.06 ± 0.05 (ranging from 3 to 21 piglets), with an average gestation length of 115.9 ± 0.04 days (ranging from 110 to 121 days) (Table 1). The average number of stillborn piglets was 1.46 ± 0.03, and the percentage of stillborn piglets in the litter varied from 0 to 100%, with a mean of 13.7 ± 0.32%. The average birth weight of live piglets ranged from 1.0 to 2.0 kg (with a mean of 1.80 ± 0.002 kg), while the average litter weight was 15.6 ± 0.08 kg. Notably, for all reproductive traits (except for the total number of piglets in the litter at birth), there was significant skewness in the distribution, particularly for the number and percentage of stillborn piglets in the litter.

Gestation length exhibited very high levels of both between- and within-breed variability (Table 2). The shortest average gestation length was observed for the indigenous Croatian breed, Banija spotted pig (113.0 days), the Chinese Qingping pig (113.6 days), and crosses between the European Hampshire and Indian Desi breeds (113.6 days). In contrast, Berkshire sows had an average gestation length of nearly five days longer (118.4 days).

Table 2*. Gestation length by breed/genotype of the sow and country of origin, days*

Sow breed/crossbreed	Country	*n*	*Mean*	*min – max*	*SD*	*CV, %*	Source
Berkshire	Poland	58	118.4	-	2.54	2.15	B. Nowak *et al.*(2020b)
Large White	Thailand	9,655	116.7	110 – 122	1.38	1.18	R. Bumpenkul & N. Imboonta (2021)
Large White	China	19,306	115.1	105 – 127	1.81	1.57	G. Yu *et al.* (2022)
Large White	Poland	258	114.9	-	1.41	1.23	B. Nowak *et al.* (2020b)
Large White	Japan	8,649	114.0	110 – 118	1.30	1.14	S. Ogawa *et al.* (2019)
Large White × Landrace	USA	473	115.8	113 – 119	0.80	0.69	K.M. Gourley *et al.* (2020)
Large White × Landrace	USA	728	115.5	113 – 119	1.30	1.13	K.M. Gourley *et al.* (2020)
Hampshire	Poland	32	115.1	-	1.24	1.08	B. Nowak *et al.* (2020b)
Hampshire × Desi	India	149	113.6	-	1.40	1.23	T. Aeir *et al.* (2020)
Duroc	Thailand	5,042	115.6	110 – 122	1.49	1.29	R. Bumpenkul & N. Imboonta (2021)
Duroc	China	1,887	115.6	108 – 119	1.20	1.04	Y. Yang *et al.* (2023)
Duroc	Poland	99	114.6	-	2.15	1.88	B. Nowak *et al.* (2020b)
Duroc	Ukraine	1,333	114.9	110 – 120	1.68	1.46	own data
Yorkshire	China	74,796	114.1	104 – 124	1.48	1.30	Y. Yang *et al.* (2023)
Yorkshire	Poland	139	115.4		1.86	1.61	B. Nowak *et al.* (2020b)
Landrace	Thailand	14,112	116.8	110 – 122	1.34	1.15	R. Bumpenkul & N. Imboonta (2021)
Landrace	China	21,787	115.9	106 – 124	1.45	1.25	Y. Yang *et al.* (2023)
Landrace	Poland	150	114.7	-	1.64	1.43	B. Nowak *et al.* (2020b)
Landrace	Japan	10,637	114.0	110 – 118	1.30	1.14	S. Ogawa *et al.* (2019)
Landrace	Ukraine	1,530	116.7	110 – 121	1.71	1.47	own data
Landrace × Yorkshire	Thailand	13,421	114.8	109 – 120	1.80	1.57	P. Tospitakkul *et al.* (2019)
Landrace × Yorkshire	Poland	556	117.6	113 – 121	1.30	1.11	A. Pietruszka *et al.* (2020)
Landrace × Yorkshire	Vietnam	210	115.3	110 – 120	1.80	1.56	N.H. Nam & P. Sukon (2020a)
Landrace × Yorkshire	Vietnam	1,020	114.8	105 – 126	1.60	1.39	N.H. Nam & P. Sukon (2020b)
Banija spotted pig	Croatia	69	113.0	-	1.63	1.44	S. Menčik *et al.* (2019)
Qingping pig	China	398	113.6	110 – 117	1.23	1.08	Z. Liu *et al.* (2022)

Note: *CV – coefficient of variation*
Source: *developed by the authors*

On the other hand, the estimates obtained from different countries and herds also varied significantly. For example, for a Large White herd in Japan, the average gestation length was estimated at 114.0 days, while in Thailand, for animals of the same breed, the estimated gestation length was 116.7 days. Gestation length was characterised by a very low level of individual variability. The coefficient of variation for this trait varied within a range of only 1-2% for different herds (Table 2). For the animals in the experimental herd, this estimate was 1.65%. The widest range of gestation length values obtained for individual sows included an interval from 104 to 127 days, although most sows farrowed 110-120 days after insemination.

Gestation length is characterised by relatively high heritability (h^2) and repeatability estimates compared to other reproductive traits in sows. For example, for Large White, Landrace, and Duroc sows, heritability estimates ranged from 0.26 to 0.32, while similar estimates for the total number born and number born alive were significantly lower (0.05-0.13 and 0.07-0.12, respectively). Notably, gestation length also exhibited a higher level of repeatability compared to other reproductive traits. In the study by Y. Yang *et al*. (2023), heritability estimates for gestation length were even higher – 0.43, 0.28, and 0.33 for Duroc, Landrace, and Yorkshire sows, respectively. For Landrace and Large White sows in Japan, heritability estimates for gestation length were 0.29 and 0.34, and repeatability estimates were 0.38 and 0.40, respectively. In contrast, for other traits characterising litter size, these estimates were significantly lower, ranging from 0.08 to 0.18 and 0.13 to 0.24, respectively.

The influence of sow and sire boar breed on the variability of reproductive traits. A significant effect of the sow breed on the expression of her reproductive traits included in the analysis was established, except for the number and proportion of stillborn piglets in the litter (Table 3).

***Table 2**. LSM estimates (± SE) of sow reproductive traits depending on their breed*

Trait (unit of measurement)	Sow breed		*P*
	DR (*n* = 1,309)	LN (*n* = 1,508)	
GL (days)	114.9 ± 0.05a	116.6 ± 0.05b	< 0.001
TNB (heads)	9.36 ± 0.08a	10.74 ± 0.08b	< 0.001
NBA (heads)	8.07 ± 0.07a	9.30 ± 0.08b	< 0.001
NSB (heads)	1.29 ± 0.05a	1.44 ± 0.06a	ns
SBR (%)	12.8 ± 0.46a	12.5 ± 0.49a	ns
LWB (kg)	14.5 ± 0.13a	16.6 ± 0.13b	< 0.001
MBW (kg)	1.80 ± 0.004a	1.79 ± 0.004b	< 0.001

***Note:** P – significance level. ns – P > 0.05. Significant differences between means of individual subgroups (P < 0.05) based on Tukey's multiple comparison test are indicated by different letters*
***Source:** developed by the authors*

Duroc sows performed less favourably than Landrace sows in terms of gestation length, total number of piglets born, number of piglets born alive, and consequently, total litter weight at birth (in all cases: $P < 0.001$). However, the average birth weight of piglets from Duroc sows was significantly higher ($P < 0.001$) compared to those from Landrace sows. Previous studies have already established that sow breed has a significant impact on gestation length. For instance, R. Bumpenkul and N. Imboonta (2021) demonstrated that Large White sows (116.7 days) and Landrace sows (116.7 days) had significantly longer gestation lengths ($P < 0.001$) compared to Duroc sows (115.6 days). Furthermore, significant differences were also observed between the studied breeds in terms of total number of piglets born, as well as the number of live and stillborn piglets. Landrace and Large White sows exhibited the highest values for these traits. In the study by Y. Yang *et al.* (2023), the average gestation length for Duroc, Landrace, and Yorkshire sows was 115.6, 115.9, and 114.1 days, respectively. Similar differences were observed in terms of the total number of piglets born, the number of live and stillborn piglets, total litter weight, and average birth weight. In the study by B. Nowak *et al.* (2020a), it was also shown that sow breed had a significant impact on reproductive traits related to litter size (total number born, number born alive, proportion of stillbirths, etc.). However, no significant effect of sow breed on the number of stillborn piglets was demonstrated, as in the current study. Large White and Landrace sows exhibited the best reproductive performance. A significant effect of the sire boar breed on sow reproductive traits was established, except for gestation length and total number born (Table 4).

***Table 4**. LSM estimates (± SE) of sow reproductive traits depending on sire boar breed*

Trait (unit of measurement)	Sire boar breed			*P*
	DR (*n* = 827)	LN (*n* = 1,353)	LW (*n* = 637)	
GL (days)	115.7 ± 0.07a	115.9 ± 0.05a	115.8 ± 0.07a	ns
TNB (heads)	10.10 ± 0.11a	9.93 ± 0.08a	10.12 ± 0.10a	ns
NBA (heads)	8.48 ± 0.10a	8.53 ± 0.07a	9.05 ± 0.09b	< 0.001
NSB (heads)	1.62 ± 0.07c	1.40 ± 0.06b	1.08 ± 0.07a	< 0.001
SBR (%)	15.1 ± 0.61c	12.9 ± 0.48b	9.9 ± 0.59a	< 0.001
LWB (kg)	14.9 ± 0.17b	15.4 ± 0.13a	16.3 ± 0.16a	< 0.001
MBW (kg)	1.76 ± 0.005b	1.81 ± 0.004a	1.80 ± 0.005a	< 0.001

***Note:** P – significance level. ns – P > 0.05. Significant differences between means of individual subgroups (P < 0.05) based on Tukey's multiple comparison test are indicated by different letters*
***Source:** developed by the authors*

The average number of live piglets in the litter at birth, as well as the total litter weight at birth, was significantly ($P < 0.001$) higher in sows inseminated with semen from Large White sire boars (9.05 piglets and 16.3 kg, respectively) compared to those inseminated with semen from Duroc or Landrace sire boars. Birth losses (i.e., the number and percentage of stillborn piglets) were highest in sows inseminated with Duroc sire boar semen (1.62 piglets and 15.1%, respectively), and lowest in sows inseminated with Large White sire boar semen (1.08 piglets and 9.9%, respectively). Sows inseminated with Landrace sire boar semen occupied an intermediate position and differed significantly from both groups (1.40 piglets and 12.9%, respectively). The average birth weight of a live piglet was significantly ($P < 0.001$) higher in sows inseminated with semen from Landrace sire boars (1.81 kg) and Large White boars (1.80 kg) compared to those inseminated with Duroc sire boar semen.

In the study by M.L.M. Pedersen *et al.* (2019), it was found that sows inseminated with semen from Pietrain sire boars had, on average, 0.5 more live piglets in the litter at birth compared to those inseminated with Duroc sire boar semen. However, the mortality rate of suckling piglets before weaning was higher in the offspring from Pietrain sire boars. In the study by A. Kramarenko *et al.* (2023), it was previously shown that the percentage of stillborn piglets in litters from sows inseminated with Duroc sire boar semen was significantly higher ($P < 0.001$) compared to those inseminated with semen from Ukrainian Meat breed, Large White, or Landrace sire boars. S. Menčik *et al.* (2020) demonstrated a significant ($P < 0.05$) influence of the sire boar on the number of stillborn piglets in the litter from crossbred sows (Landrace × Large White) during the second, while the duration of gestation was significantly associated with the total number of piglets born. This influence can partly be explained by the characteristics of the ejaculate, which significantly differ between boars of different breeds (Kamanova *et al.*, 2021). In the study by H. Petrocelli and C. Batista (2019), it was shown that the origin of the boar affected both the fertility of the sows and the total number of piglets born. A significant combined effect of both sow breed and sire boar breed on the reproductive traits of sows was also established, again, except for gestation length and total number of piglets in the litter (Table 5).

***Table 5**. Variability estimates (Mean ± SE) of reproductive traits in sows depending on their breed and sire boar breed*

Trait (unit of measurement)	Sow breed: DR			Sow breed: LN			$P_{S/B}$
	Sire boar breed: DR	LN	LW	DR	LN	LW	
n	797	235	301	42	1,139	348	
GL (days)	114.8 ± 0.06a	115.1 ± 0.11a	114.9 ± 0.09a	116.7 ± 0.25b	116.7 ± 0.05b	116.6 ± 0.09b	ns
TNB (heads)	9.39 ± 0.08a	9.47 ± 0.15a	9.27 ± 0.13a	10.45 ± 0.39ab	10.60 ± 0.08b	10.81 ± 0.15b	ns
NBA (heads)	7.78 ± 0.08a	8.09 ± 0.16ab	8.19 ± 0.13ab	9.43 ± 0.34bcd	9.01 ± 0.07c	9.74 ± 0.14d	0.006
NSB (heads)	1.61 ± 0.06b	1.38 ± 0.13ab	1.08 ± 0.08a	1.02 ± 0.24ab	1.60 ± 0.06b	1.07 ± 0.08a	0.009
SBR (%)	16.4 ± 0.64c	13.3 ± 1.24abc	11.5 ± 0.95ab	8.4 ± 1.96abc	14.0 ± 0.48bc	9.5 ± 0.78a	0.010
LWB (kg)	13.9 ± 0.13d	15.3 ± 0.27a	14.9 ± 0.22a	16.8 ± 0.64abc	16.4 ± 0.13b	17.6 ± 0.24c	< 0.001
MBW (kg)	1.77 ± 0.004b	1.85 ± 0.009c	1.81 ± 0.007a	1.79 ± 0.025abc	1.81 ± 0.004a	1.80 ± 0.008ab	0.013

***Note:** PS/B – significance level for the combined effect of the factors "sow breed" and "sire boar breed". ns – P > 0.05. Significant differences between means of individual subgroups (P < 0.05) based on Tukey's multiple comparison test are indicated by different letters*
***Source:** developed by the authors*

The best reproductive performance (highest number of live piglets in the litter, highest total litter weight at birth, and the lowest number and percentage of stillborn piglets in the litter) was observed in Landrace sows inseminated with semen from Large White or Landrace sire boars. In contrast, the poorest performance was observed in Duroc sows inseminated with Duroc sire boar semen. The highest average birth weight was found in piglets born to Duroc sows inseminated with semen from Landrace sire boars.

The study by O.L. Bondoc *et al.* (2019) demonstrated that the reproductive qualities of sows and the traits of piglets at birth and weaning were influenced by the combination of the sow and sire boar breeds (Large White and Landrace). Offspring from crossbred litters exhibited better performance than purebred animals. For instance, crossbred animals of Large White × Landrace showed significantly ($P < 0.05$) more teats than animals of Landrace × Large White. In the case of Chinese-origin crossbred pigs (Shanxia black pig and Lulai black pig), direct crosses had better reproductive traits than reciprocal crosses (Yan *et al.*, 2021). Similarly, the research by J.K. Hagan and N.N. Etim (2019) showed that purebred Large White sows produced fewer piglets at birth (12.5 piglets) compared to crossbred animals (Large White × Duroc), which had an average of 14.2 piglets. However, the study by H. Jankowiak *et al.* (2020) indicated that the genotype of the piglets (whether purebred or crossbred) had a lesser impact than the genotype of the sow itself.

The influence of the year and season of farrowing on the reproductive traits of sows. Sows that farrowed in different years significantly differed in all reproductive traits, except for lactation duration, which varied within a very narrow range of 115.7-115.9 days (Table 6).

Table 6*. LSM estimates (± SE) of reproductive traits in sows depending on the year of farrowing*

Trait (unit of measurement)	Year of farrowing				P
	2010 ($n = 713$)	2011 ($n = 778$)	2012 ($n = 848$)	2013 ($n = 478$)	
GL (days)	115.7 ± 0.06a	115.8 ± 0.06a	115.7 ± 0.06a	115.9 ± 0.08a	ns
TNB (heads)	9.77 ± 0.10a	10.44 ± 0.09b	9.97 ± 0.09a	10.02 ± 0.12ab	< 0.001
NBA (heads)	8.34 ± 0.09b	8.83 ± 0.09a	8.78 ± 0.08a	8.80 ± 0.11a	< 0.001
NSB (heads)	1.44 ± 0.07bc	1.62 ± 0.07c	1.19 ± 0.06a	1.22 ± 0.08ab	< 0.001
SBR (%)	13.7 ± 0.56bc	14.4 ± 0.54c	10.9 ± 0.50a	11.6 ± 0.69ab	< 0.001
LWB (kg)	14.9 ± 0.15a	16.5 ± 0.15c	15.6 ± 0.14b	15.1 ± 0.19ab	< 0.001
MBW (kg)	1.79 ± 0.005a	1.87 ± 0.004c	1.78 ± 0.004a	1.72 ± 0.006b	< 0.001

Note: *trait designations as in Table 1. P – significance level. ns – P > 0.05. Significant differences between means of individual subgroups (P < 0.05) based on Tukey's multiple comparison test are indicated by different letters*
Source: *developed by the authors*

The best performance for various reproductive traits was observed in different years. For instance, the highest total number of piglets at birth was recorded in 2011 (10.44 piglets), while the highest *LSM* estimates for the number of live piglets at birth were observed during 2011-2013. The season of farrowing also significantly affected the duration of gestation and other litter characteristics, except the number and proportion of stillborn piglets in the litter (Table 7).

Table 7*. LSM estimates (± SE) of reproductive traits in pigs depending on the season of farrowing*

Trait (unit of measurement)	Season of farrowing				P
	Winter ($n = 613$)	Spring ($n = 848$)	Summer ($n = 819$)	Autumn ($n = 537$)	
GL (days)	116.2 ± 0.07b	115.8 ± 0.06a	115.6 ± 0.06a	115.5 ± 0.08a	< 0.001
TNB (heads)	10.09 ± 0.10ab	10.31 ± 0.09b	9.88 ± 0.09a	9.93 ± 0.11ab	0.003
NBA (heads)	8.60 ± 0.09a	8.94 ± 0.08b	8.58 ± 0.08a	8.62 ± 0.10a	0.005
NSB (heads)	1.48 ± 0.07a	1.37 ± 0.06a	1.30 ± 0.06a	1.31 ± 0.08a	ns
SBR (%)	13.5 ± 0.59a	12.8 ± 0.51a	12.1 ± 0.52a	12.3 ± 0.66a	ns
LWB (kg)	15.4 ± 0.16a	16.1 ± 0.14b	15.3 ± 0.14a	15.2 ± 0.18a	< 0.001
MBW (kg)	1.80 ± 0.005a	1.81 ± 0.004b	1.79 ± 0.004a	1.77 ± 0.005ab	< 0.001

Note: *P – significance level. ns – P > 0.05. Significant differences between means of individual subgroups (P < 0.05) based on Tukey's multiple comparison test are indicated by different letters.*
Source: *developed by the authors*

The highest ratings for both litter size and the total litter weight and the weight of individual piglets were obtained for sows that farrowed during the spring season (i.e., from March to May), while the poorest performance was most often observed in animals that farrowed during the summer season. T.J. Zindove *et al.* (2021) previously noted significant differences between the individual years of the study regarding the reproductive traits of crossbred sows (Landrace × Large White) under conditions in Zimbabwe. A highly significant ($P < 0.001$) effect of the year and season of farrowing on litter size and the weight of individual piglets at birth was also established for Yorkshire sows, whereas no such pattern was observed among Duroc sows.

The significant influence of the farrowing season on reproductive traits has also been demonstrated for Large White sows and their crosses with Duroc, housed in Ghana (Hagan & Etim, 2019). Better results were obtained for farrowings that occurred during the cooler rainy season of the year, compared to those during the hot dry season. These differences applied to both litter size and piglet birth weight. Furthermore, the combined effects of second- and third-order factors, such as "season of the year" × "breed of sow" and "season of the year" × "parity" × "breed of sow", were noted for both litter size at birth and weaning, as well as for piglet birth weight. This may be linked to a reduction in the quality and quantity of sire boar semen production, as well as a decline in the milk production of sows under heat-stress conditions. In crossbred sows (Landrace × Large White), it was shown that the average weight of live piglets at birth was significantly lower for farrowings that occurred in July.

In contrast to the findings of the current study, which showed no effect of the farrowing season on the number and proportion of stillborn piglets in the litter, S. Schild *et al.* (2019) indicated that the risk of stillbirth among crossbred sows (Landrace × Yorkshire) significantly increased during the warmer months, particularly when the air temperature exceeded 27°C. On the other hand, for crossbred pigs (Hampshire × Desi) in India, the farrowing season did not affect either the duration of gestation or the size and weight of the litter at birth (Aeir *et al.*, 2020).

Relationship between gestation length and reproductive traits in sows. Eight publications (i.e., 7.9% of the total number of articles analysed) from the period 2019-2023 were selected, containing estimates of the phenotypic correlation coefficient (Pearson's) between gestation length and reproductive traits in sows. The sows represented widely distributed cross-border breeds (Duroc, Landrace, Large White, and Yorkshire) or their crosses (Landrace × Large White, Landrace × Yorkshire). Additionally, data obtained by the authors for the experimental group of sows were included in the meta-analysis (Table 8). As a result, the initial database for the meta-analysis, containing estimates of the phenotypic correlation coefficient, included 49 entries.

***Table 8**. Correlation coefficients between gestation length and reproductive traits by sow breed*

Trait (unit of measurement)	Sow breed	
	DR ($n = 1{,}333$)	LN ($n = 1{,}529$)
TNB (heads)	-0.167 ($P < 0.001$)	-0.123 ($P < 0.001$)
NBA (heads)	-0.076 ($P = 0.006$)	-0.049 (ns)
NSB (heads)	-0.133 ($P < 0.001$)	-0.121 ($P < 0.001$)
SBR (%)	-0.059 ($P = 0.032$)	-0.088 ($P = 0.001$)
LWB (kg)	-0.072 ($P = 0.009$)	-0.057 ($P = 0.026$)
MBW (kg)	0.015 (ns)	-0.015 (ns)

Note: *P – significance level. ns – P > 0.05*
Source: *developed by the authors*

Due to the very high estimates of the heterogeneity index (I^2) for all the included data (97.0100.0%), a random-effects model was used in all cases for the meta-analysis (Table 9).

***Table 9**. Results of the meta-analysis of the correlation coefficient between gestation length and reproductive traits in sows*

Trait (unit of measurement)	K	I^2, %	χ^2	P	r_{gen}	95% CI
TNB (heads)	12	98.0	475.65	< 0.01	-0.12	-0.16...-0.08
NBA (heads)	11	98.0	472.22	< 0.01	-0.11	-0.15...-0.06
NSB (heads)	13	100.0	161.51	< 0.01	-0.02	-0.06...+0.01
SBR (%)	6	97.0	199.72	< 0.01	-0.12	-0.18...-0.06
LWB (kg)	7	100.0	99.04	< 0.01	+0.06	+0.01...+0.11

Note: *K – number of studies included in the meta-analysis. P – significance level. I^2 – heterogeneity index estimate. r_{gen} – "general" estimate of the phenotypic correlation coefficient. 95% CI – 95% confidence interval for the "general" estimate*
Source: *developed by the authors*

For the correlation coefficient between gestation length and the total number of piglets in the litter, as well as the number of live piglets at birth, the "general" estimates were -0.12 and -0.11, respectively. In both cases, the 95% confidence interval for the "general" estimates did not include zero, therefore, a significant (negative) relationship between these two traits and gestation length can be considered established. Regarding the number of stillborn piglets in the litter, the "general" estimate was very low (-0.02), and it fell within the 95% confidence interval (-0.06 to +0.01). Hence, in this case, it cannot be considered that a significant relationship between gestation length and the number of stillborn piglets in the litter has been established.

In the analysis of the relationship between gestation length and the total litter weight at birth, the "general" estimate of the phenotypic correlation coefficient was -0.12 (with a 95% confidence interval from -0.18 to -0.06). In this case, zero does not fall within the confidence interval, so it can be considered that a significant (negative) relationship between gestation length and total litter weight at birth has been established. Finally, for the relationship between gestation length and the average birth weight of live piglets, the "general" estimate of the phenotypic correlation coefficient was +0.06 (with a 95% confidence interval from +0.01 to +0.11). As in the previous case, since zero does not fall within the confidence interval, a significant (positive) relationship between these traits can be considered established. Based on the results of the meta-analysis, the following conclusions can be drawn regarding the relationships between the gestation length of sows and the traits of their litters at birth (Fig. 1).

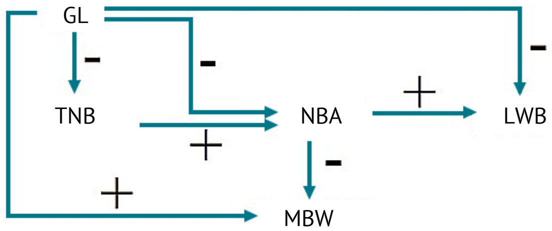

***Figure 1**. Schematic of the relationships between gestation length and reproductive traits of sows based on the results of the meta-analysis*
***Note:** the symbol "+" indicates a significant positive relationship, while the symbol "–" indicates a significant negative relationship between the corresponding traits*
***Source:** developed by the authors*

There is a negative relationship between gestation length and the total number of piglets in the litter at birth. However, since the number of live piglets in the litter at birth (i.e., the realised litter size) is largely determined by the potential litter size, which includes both live and stillborn piglets, the relationship between gestation length and the number of live piglets in the litter at birth will also be negative. The number of live piglets in the litter at birth significantly influences the total litter weight at birth. Therefore, the relationship between this trait and gestation length will also be negative. Finally, as both the total number of piglets and the number of live piglets at birth increase, the average birth weight of live piglets will decrease, and consequently, the relationship between this trait and gestation length will be positive. Notably, the relationship between gestation length and the total number of piglets, as well as the number of live piglets in the litter at birth, often follows a nonlinear pattern (Pietruszka *et al.*, 2020). In this case, the descending right-hand portion of this curve is more pronounced, which explains why the correlation coefficient between gestation length and litter traits at birth is negative.

On the other hand, a gestation length that is no shorter than the average (usually 114 days) promotes better piglet development at birth and, accordingly, a lower level of postnatal mortality. Furthermore, the number of stillborn piglets in the litter increased with a decrease in gestation length, while the average weight of a piglet at birth tended to decrease as litter size increased (Ogawa *et al.*, 2019). In the study by N.H. Nam and P. Sukon (2020b), it was shown that a gestation length shorter than 114 days is a significant risk factor for stillbirth among Landrace × Yorkshire sows in Vietnam. Sows with a gestation length of less than 114 days had 1.80 times higher ($P < 0.001$) chances of having at least one stillborn piglet in the litter. This may be related to underdeveloped lungs in piglets born during early farrowing (before 114 days of gestation). Although the current study found a significant (negative) correlation between gestation length and the number (and proportion) of stillborn piglets in the litter (Table 8), the generalised results from the meta-analysis for different breeds and/or herds did not confirm the widespread nature of this pattern. Thus, gestation length in sows is a complex trait, shaped by both genotypic (sow and sire boar breed) and environmental (year and season of farrowing) factors, which, in turn, influence the variability in litter size at birth.

CONCLUSIONS

The average gestation length for the animals in the experimental herd was 115.9 ± 0.04 days (ranging from 110 to 121 days) and was characterised by very low inter-individual variability (the coefficient of variation was only 1.65%). A significant effect of sow breed on gestation length and other litter traits at birth was confirmed (in all cases: $P < 0.001$), except the number and proportion of stillborn piglets in the litter. Furthermore, no significant effect of the sire boar breed on gestation length or total litter size was found for sows inseminated with their semen. Overall, the best reproductive performance (maximum number of piglets born in the litter with the minimum level of stillbirths) was observed in Landrace sows inseminated with the semen of Large White or Landrace sire boars. The year of farrowing significantly affected all reproductive traits of the sows (in all cases: $P < 0.001$), except for gestation length. The highest gestation lengths were recorded for sows that were farrowed in winter, while for the remaining reproductive traits, the best results were observed in spring farrowings. The meta-analysis results indicate that the "general" phenotypic correlation coefficients between gestation length, on the one hand,

and total litter size, number of live piglets in the litter, and total litter weight at birth, on the other hand, were significant and negative (-0.12 to -0.11). The correlation between gestation length and the average weight of live piglets at birth was significant and positive (+0.06). The meta-analysis results did not support the presence of a significant relationship between gestation length and the number of stillborn piglets in the litter. Future research perspectives include analysing the impact of sow gestation length on the growth and survival of suckling piglets until weaning.

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CONFLICT OF INTEREST

None.

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Аналіз мінливості тривалості поросності свиноматок та її зв'язок із ознаками гнізда при народженні

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Анотація. Тривалість поросності є важливою комплексною полігенною ознакою свиноматки, що значною мірою формує її продуктивні якості та впливає на формування плоду протягом ембріонального періоду. Головною метою даного дослідження став аналіз впливу генотипових (порода свиноматки та кнура-плідника) та паратипових (рік та сезон опоросу) факторів на мінливість тривалості поросності свиноматок та визначення характеру зв'язку тривалості поросності з ознаками гнізда при народженні (із використанням алгоритму мета-аналізу).Для аналізу було використано первинні матеріали щодо відтворювальних ознак свиноматок основного стада приватне акціонерне товариство «Племзавод «Степной» Запорізької області, отримані протягом 2010-2013 рр. Для тварин дослідного стада оцінка середньої тривалості поросності складала 115,9 ± 0,04 днів (із розмахом від 110 до 121 дня). При цьому, тривалість поросності характеризувалася дуже низьким рівнем міжіндивідуальної мінливості (оцінка коефіцієнта варіації складала лише 1,65 %). Свиноматки породи дюрок поступалися тваринами породи ландрас за тривалістю поросності, загальною кількістю поросят та кількістю живих поросят у гнізді при народженні (у всіх випадках: $P < 0{,}001$). Встановлено вірогідний вплив породи кнура-плідника на відтворювальні ознаки свиноматок, за виключенням тривалості поросності та загальної кількості поросят у гнізді. Найвищі оцінки тривалості поросності було отримано протягом зимових місяців року, у той час як для решти репродуктивних ознак свиноматок найкращі оцінки було отримано для весняного періоду. В результаті мета-аналізу встановлено, що «генеральні» оцінки коефіцієнту фенотипової кореляції між тривалістю поросності та загальною кількістю поросят у гнізді, кількістю живих поросят у гнізді і загальною масою гнізда при народженні були вірогідні та від'ємні, у той час як оцінка між тривалістю поросності та середньою масою живого поросяти при народженні була вірогідна та додатна

Ключові слова: ознаки відтворення; генотипові та паратипові фактори; мета-аналіз; свині