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Risk Factors for Second Litter Syndrome in Landrace × Yorkshire Sows in Tropical Conditions

N. H. Nam[1], D. T. K. Lanh[1], N. V. Thanh[1], B. V. Dung[1], B. T. A. Dao[2], & P. Sukon[3,4,*]
[1]Department of Animal Surgery and Theriogenology, Faculty of Veterinary Medicine, Vietnam National University of Agriculture, Hanoi, Vietnam
[2]Department of Veterinary Pathology, Faculty of Veterinary Medicine, Vietnam National University of Agriculture, Hanoi, Vietnam
[3]Faculty of Veterinary Medicine, Khon Kaen University, Thailand
123 Moo 16 Mittraphap Rd., Nai-Muang, Muang District, Khon Kaen 40002, Thailand
[4]Research Group for Animal Health Technology, Khon Kaen University, Thailand
123 Moo 16 Mittraphap Rd., Nai-Muang, Muang District, Khon Kaen 40002, Thailand
*Corresponding author: sukonp@kku.ac.th
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ABSTRACT

Second litter syndrome (SLS), defined as an equal or lower number of piglets born alive (NBA) in the second parity compared to that in the first, is a major reproductive concern in commercial sow herds worldwide. This study aimed to identify factors associated with SLS under tropical conditions in Vietnam. Data from 3,957 Landrace × Yorkshire sows farrowing the second litter between 2024 and 2025 were analyzed using logistic regression. The overall incidence of SLS was 56.8%, with mean NBA of 12.7 in both parities. In the multivariable model 1, NBA in the first parity (NBA1) was the strongest predictor, accounting for 50.3% of the explained variation (OR=2.3, 95% CI: 2.2-2.4, p<0.001). Age at insemination after weaning between 344 and 440 days increased the odds of SLS by 1.4-1.8 times compared with the value >470 days. Model 2, excluding NBA1, identified additional risk factors, including litter size at weaning (LSW), weaning-to-service interval (WSI), and month of insemination after the first weaning. Sows that weaned >14 piglets had threefold higher odds of SLS compared to those weaning fewer than 11 piglets (p<0.001). A shorter WSI (0-10 days) increased the risk of SLS by 1.3-1.4 times compared to a WSI>17 days (p<0.009). Compared with the sows inseminated in May-August, the sows inseminated in September-April had 1.7-2.1 times higher odds of SLS (p<0.001). This study showed a high prevalence of SLS and its association with several factors under tropical conditions. To maintain overall herd productivity while lowering the risk of SLS, farm management should focus on sows with a large NBA1, sows' recovery before insemination, and the mitigation of metabolic stress.

Keywords: age at first insemination; reproductive parameters; risk factor; season; second litter syndrome

INTRODUCTION

Commonly, the number of piglets born alive (NBA) in the second parity is higher than that in the first parity (Gruhot *et al*., 2017; Ju *et al*., 2021; Vargovic *et al*., 2022; Estrada *et al*., 2024; Nam *et al*., 2024a). However, many sows in parity 2 have an NBA equal to or lower than those in parity 1 (Thomas *et al*., 2018; Buthelezi *et al*., 2024), a condition known as second litter syndrome (SLS) (Segura Correa *et al*., 2013). Previous studies have reported high incidences of SLS in many countries. In the United States, a study documented that 54% of sows acquired SLS (Morrow *et al*., 1992), while research in Japan showed that 49.5% of sows acquired SLS (Saito *et al*., 2010). Similar values have also been reported in Mexico (Segura-Correa *et al*., 2014; Segura Correa *et al*., 2013) and Brazil (Rabelo *et al*., 2016), ranging from 48.1% to 55.8%. In Europe, the incidence of SLS varied significantly, ranging from 33.3% in the Netherlands (Sell-Kubiak et al., 2021) to 56.6% in Spain (Sanz-Fernández *et al*., 2022). Recently, research conducted under tropical conditions has demonstrated a high incidence of 47.8% in Vietnam (Nam *et al*., 2024b). These findings suggest that SLS remains a common reproductive issue in commercial sow herds worldwide.

SLS has been shown to be negatively associated with sow productivity. Compared to sows without SLS, sows with SLS had 0.3 fewer NBA in the first two parities (Saito *et al*., 2010). Another study also reported that SLS reduced NBA in the first two parities by 1.34 piglets, and by 0.11-0.47 piglets in later parities (Sell-Kubiak *et al*., 2021). In a recent study, we found that SLS reduced the cumulative NBA in the first 2 parities by 0.8 piglets, although no significant difference was detected when considering the total NBA from parity one to five (Nam *et al*., 2024b). However, sows with a small litter size in the second parity had a higher odds of having a small litter size in subsequent parities and were associated with an elevated culling risk (Hoving *et al*., 2010). These findings highlight the economic and biological significance of preventing SLS from maintaining herd productivity and profitability.

Previous studies have found several factors associated with SLS in sows. NBA in the first parity (NBA1) has a strong association with SLS. Increased NBA1 elevated the likelihood of SLS (Morrow *et al*., 1992; Segura Correa *et al*., 2013; Segura-Correa *et al*., 2014; Sanz-Fernández *et al*., 2022). The weaning-to-service interval (WSI) is another significant determinant. A shorter WSI was associated with an increased risk of SLS (Morrow *et al*., 1992; Segura Correa *et al*., 2013; Segura-Correa *et al*., 2014). However, the role of seasons is less consistent. While Segura Correa *et al*. (2013) reported higher odds during rainy (OR=1.20) and dry (OR=1.24) seasons compared to the windy season, later research found no significant seasonal effect (Segura-Correa *et al*., 2014; Sell-Kubiak *et al*., 2021). Lactation length also appeared relevant, as longer lactations were associated with a reduced risk of SLS in European herds (Sell-Kubiak *et al*., 2021), and distinct lactation lengths were linked to changes in the difference in NBA between parity 1 and 2 (Sanz-Fernández *et al*., 2022). Additionally, sows first farrowed at an average of 337 days lost nearly twice as many piglets at parity 2 compared to those farrowed at an average of 474 days (Sanz-Fernández *et al*., 2022).

Taken together, these findings suggest that SLS involves both physiological and management-related factors in several production systems. However, most of these studies were conducted in temperate regions. Therefore, there is a need to evaluate these factors under tropical conditions, where different environmental and managerial situations may exert distinct impacts on SLS occurrence. To address this knowledge gap, the present study aimed to evaluate the influence of age at first artificial insemination, age at first farrowing, number of piglets born alive at first parity, litter birth weight at first parity, number of piglets weaned, litter weaning weight, weaning-to-service interval, age at insemination after weaning, month at insemination after weaning, and month of second farrowing on the incidence of SLS in a commercial sow herd under tropical conditions in Vietnam.

MATERIALS AND METHODS

Ethical Approval

Although this study relied solely on pre-existing farm records and did not involve animal handling or experimental procedures, all farm procedures were carried out in accordance with the institutional animal care and use guidelines issued by Vietnam National University of Agriculture.

Animal and General Management

This study was conducted in central Vietnam on a commercial swine farm housing about 5,000 crossbred Landrace × Yorkshire sows. Gilts were group-housed until puberty and bred upon reaching ≥135 kg body weight, typically at the second or third estrus. Natural farrowing was permitted, with induction on day 116 of gestation using 175 μg of cloprostenol (2 mL, Hanprost, Hanvet, Vietnam) if parturition had not occurred. Dystocia was managed with 20 IU oxytocin (Dona oxytocin, DonaVet, Vietnam) or, when necessary, manual extraction. All hormonal injections were administered in the perivulvar region.

Post-weaning, sows received 6 ml vitamin ADE intramuscularly (500,000 IU vitamin A, 250,000 IU vitamin D, 120 mg vitamin E; DonaVet, Vietnam) and were exposed to intact Meishan boars for ≥6 h/day (1 boar/12 sows). Estrus detection was performed once daily in the morning via back-pressure test in the presence of a boar, lasting seconds to 20 s depending on estrus intensity. Sows not in estrus within 7 days post-weaning received a second vitamin ADE injection. If estrus was absent by day 14, an alternate-day feed restriction was applied. Between days 18-21, non-cycling sows were treated with 400 IU of eCG and 200 IU of hCG (2 ml, Heat 5×, Dong Bang Co. Ltd., Korea) intramuscularly in the neck, alongside increased boar exposure (≥12 h/day) and photoperiod (≥16 h/day). Estrus sows were artificially inseminated twice using fresh semen with ≥75% motility and $\geq 3 \times 10^9$ sperm cells.

All studied sows were born between November 2022 and December 2023; insemination in primiparous sows was performed between November 2023 and January 2025; and farrowing in the second litter occurred between March 2024 and May 2025. The region's average monthly minimum-maximum temperatures (°C) were: January (15.8-20.4), February (17.1-23.6), March (19.2-25.4), April (25.0-32.9), May (25.1-31.5), June (27.3-34.5), July (27.1-34.0), August (26.8-34.6), September (25.1-32.5), October (22.7-31.4), November (20.8-29.4), and December (15.5-22.1). The mean relative humidity was about 85%-86%.

Data Collection

A substantial portion of this dataset had been used previously to examine risk factors for prolonged weaning-to-service interval in primiparous sows (Nam *et al*., 2025). From 8,830 available records, 3957 sows that farrowed their second litter and had complete data were included. The variables collected comprised sow birth date, first artificial insemination date, first farrowing date, number of piglets born alive at the first farrowing, litter birth weight, weaning date, number of piglets weaned, litter weight at weaning, date of first post-weaning insemination, and number of piglets born alive at the second farrowing.

Variable Definition

Age at first artificial insemination (AFAI, days) and age at first farrowing (AFF, days) were calculated as the intervals from birth to first AI and to first farrowing, respectively. Litter birth weight (LBW, kg) was the total weight of live-born piglets (NBA) weighing >0.85

kg. Lactation length (LL, days) was the interval from farrowing to weaning. Litter size at weaning (LSW) and litter weight at weaning (LWW, kg) were the total number and total weight of piglets weaned per litter, respectively. Weaning-to-service interval (WSI, days) was the interval from weaning to first post-weaning AI, while age at first AI post-weaning (ASAI, days) was calculated from birth to first post-weaning AI. The month of first AI post-weaning (MSAI) and the month of second farrowing (MSF) were assigned from the calendar month of the first post-weaning AI and second farrowing, respectively. Second litter syndrome was characterized by an NBA in the second litter that was lower than or comparable to the NBA in the first litter.

Statistical Analysis

Prior to analysis, independent variable were classified into different groups as follows: AFAI into 5 groups (189-230, 230-250, 250-270, 270-290, and >290 days); AFF into 5 groups (302-360, 360-380, 380-400, 400-420, and >420); LSW into 5 groups (<11, 11, 12, 13, and 14-19 piglets), LWW into 5groups (<70, 70-80, 80-90, 90-100, and 100 kg); LL into 5 groups (<22, 22-24, 25-26, 27-28, and >28 days); ASAI into 5 groups (344-400, 400-420, 420-440, 440-470, and >470 days); WSI into 4 groups (0-6, 7-10, 11-17, and >17 days); MSAI into 3 groups (December-April, May-August, and September-November); MSF into 3 groups (January-March, April-July, and August-December). NBA and LBW were treated as continuous independent variables.

Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). A two-step approach was applied: first, univariable logistic regression was used to examine associations between each independent variable and second litter syndrome; second, all variables, irrespective of univariable significance, were entered into a forward multivariable logistic regression to identify the key predictors of second litter syndrome while controlling for confounders. Due to a direct association between NBA1 and SLS, a second multivariable model was built without including NBA1 and LBW. Spearman's rho coefficients were calculated to assess correlations, and variables with r ≥ 0.7 were excluded from the same model to avoid multicollinearity (MSAI *vs*. MSF; AFAI, AFF *vs*. ASAI) (Xi *et al*., 2024). Model adequacy was evaluated using the Hosmer-Lemeshow test (Ailobhio & Ikughur, 2024). Additionally, the Brier score (Steyerberg, 2019) was calculated and a calibration plot (Fenlon *et al*., 2018; Huang *et al*., 2020) was generated if p<0.05. The models were compared using the Akaike and Bayesian Information Criteria (AIC and BIC) (Zhang *et al*., 2023). Variance inflation factors (VIF) were computed to evaluate multicollinearity (Kim, 2019) further. The area under the receiver operating characteristic curve (ROC-AUC) was calculated to evaluate the discriminatory ability of the model (Dey *et al*., 2025).

Table 1. Descriptive statistics for second litter syndrome in Landrace × Yorkshire sows

Reproductive variables	Mean±SD
Number of piglets born alive in the first litter (piglets)	12.7 ± 2.8
Number of piglets born alive in the second litter (piglets)	12.7 ± 2.6
Age at the first insemination (days)	265.9 ± 31.9
Age at the first farrowing (days)	382.5 ± 32.0
Age at insemination after weaning (days)	420.1 ± 35.8
Litter birth weight (kg)	16.6 ± 3.7
Lactation length (days)	25.4 ± 3.3
Litter size at weaning (piglets)	12.1 ± 1.6
Litter weight at weaning (kg)	83.7 ± 12.5
Weaning to service interval (days)	12.1 ± 16.7

Note: Data presented as mean and standard deviation.

RESULTS

Descriptive Statistics

The incidence of SLS in Landrace × Yorkshire sows was 56.8 (2248/3957) (Table 1). The mean NBA was 12.7±2.8 in the first litter and 12.7±2.6 in the second litter. The mean AFAI, AFF, and ASAI were 265.9±31.9, 382.5±32.0, and 420.1±35.8 days, respectively. The average of LBW was 16.6±3.7 kg, and LL was 25.4±3.3 days. At weaning, the average litter size was 12.1±1.6 piglets with a mean litter weight of 83.7±12.5 kg. The mean WSI was 12.1±16.7 days.

Univariable Analysis

Univariate analysis revealed significant associations between SLS and NBA, LBW, AFF, LSW, LWW, WSI, ASAI, and MSAI. No significant associations between SLS and AFAI and LL were detected (Table 2).

Multivariable Analysis

Model 1, including NBA1 and ASAI, explained 50.8% of the variation in SLS. NBA1 accounted for 50.3% of the explained variation, indicating that ASAI contributed only marginally. The model demonstrated good discriminative ability (ROC-AUC=0.872). Although the Hosmer-Lemeshow test indicated p<0.05, the Brier score of 0.143 and calibration plot suggested adequate calibration.

Model 2, including LSW, WSI, and MSAI, explained 4.0% of the variation in SLS. The Hosmer-Lemeshow test yielded a p-value of 0.882; however, the ROC-AUC was low at 0.595, indicating limited discriminative ability. In both models, all the VIF values were close to 1, suggesting that there was no multicollinearity.

Odds Ratios for Significant Predictors

NBA1 exhibited a strong effect on SLS (OR = 2.3, 95% CI: 2.2-2.4, p < 0.001), indicating that a larger first-litter size significantly increased the likelihood of SLS. Compared with ASAI > 470 days, sows with ASAI between 344-400 days (OR = 1.8, 95% CI: 1.3-

2.5, p=0.001) and 400–420 days (OR=1.9, 95% CI: 1.4-2.6, p<0.001) had higher odds of SLS, whereas the association weakened at 420-440 days (OR=1.4, 95% CI: 1.0-2.0, p=0.038) and was not significant at 440-470 days (p=0.149).

Compared to sows weaning fewer than 11 piglets, the odds of SLS increased progressively with larger litters: 11 piglets (OR=1.5, 95% CI: 1.1-1.9, p<0.001), 12 piglets (OR=1.9, 95% CI: 1.5-2.4, p<0.001), 13 piglets (OR=2.2, 95% CI: 1.7-2.7, p<0.001), and >14 piglets (OR=3.0, 95% CI: 2.3-3.8, p<0.001).

Regarding WSI, sows inseminated within 0-6 days (OR=1.4, 95% CI: 1.2-1.6, p<0.001) and 7-10 days (OR=1.3, 95% CI: 1.1-1.7, p=0.009) after weaning had

Table 2. Univariable analysis for potential risk factors of second litter syndrome in 3957 Landrace x Yorkshire sows

Variables	Incidence of SLS (%)	OR (95% CI)	p
Number of piglets born alive in first parity	Not applicable	2.3 (2.2-2.4)	<0.001
Litter birth weight of piglets born alive in the first parity	Not applicable	1.5 (1.4-1.5)	<0.001
Age at first insemination			
<230 days	58.4 (246/421)	1.2 (1.0-1.6)	0.115
230-250 days	57.3 (437/762)	1.2 (0.9-1.5)	0.151
250-270 days	57.6 (729/1265)	1.2 (1.0-1.4)	0.09
270-290 days	56.6 (524/925)	1.1 (0.9-1.4)	0.22
>290 days	53.4 (312/584)	1	
Age at first farrowing			
314-360 days	59.1 (525/889)	1.4 (1.1-1.8)	0.01
360-380 days	56.3 (603/1072)	1.3 (1.0-1.6)	0.08
380-400 days	57.2 (671/1174)	1.3 (1.0-1.7)	0.04
400-420 days	57.1 (291/510)	1.3 (1.0-1.7)	0.073
>420 days	50.6 (158/312)	1	
Lactation length			
0-21 days	54.4 (254/467)	1	
22-24 days	58.5 (567/969)	1.2 (0.9-1.5)	0.139
25-26 days	56.8 (596/1049)	1.1 (0.9-1.4)	0.38
27-28 days	54.7 (526/961)	1.0 (0.8-1.3)	0.902
>28 days	59.7 (305/511)	1.2 (1.0-1.6)	0.095
Litter size at weaning			
0-10 piglets	42.7 (201/471)	1	
11 piglets	51.7 (269/520)	1.4 (1.1-1.9)	0.004
12 piglets	56.8 (744/1309)	1.8 (1.4-2.2)	<0.001
13 piglets	59.5 (666/1119)	2.0 (1.6-2.5)	<0.001
14-19 piglets	68.4 (368/538)	3.0 (2.3-3.8)	<0.001
Litter weight at weaning			
<70 kg	44.4 (216/487)	1	
70-80 kg	56.5 (581/1029)	1.6 (1.3-2.0)	<0.001
80-90 kg	58.8 (779/1325)	1.8 (1.5-2.2)	<0.001
90-100 kg	58.5 (483/826)	1.8 (1.4-2.2)	<0.001
>100 kg	65.2 (189/290)	1.8 (1.4-2.2)	<0.001
Weaning to service interval			
0-6 days	58.1 (1404/2418)	1.4 (1.2-1.6)	<0.001
7-10 days	59.8 (364/609)	1.5 (1.2-1.8)	0.001
11-17 days	58.3 (81/139)	1.4 (1.0-2.0)	0.089
>17 days	50.4 (399/791)	1	
Age at first insemination post-weaning			
344-400 days	58.9 (670/1138)	1.6 (1.2-2.0)	0.001
400-420 days	59.8 (605/1011)	1.6 (1.3-2.1)	<0.001
420-440 days	54.0 (496/918)	1.3 (1.0-1.7)	0.063
440-470 days	56.3 (344/611)	1.4 (1.1-1.9)	0.017
>470 days	47.7 (133/279)	1	
Month of first insemination post-weaning			
December-April	56.4 (1498/2658)	1.6 (1.2-2.1)	<0.001
May-August	44.6 (115/258)	1	
September-November	61.0 (635/1041)	1.9 (1.5-2.6)	<0.001
The month of the second farrowing			
January-March	60.8 (640/1053)	1.6 (1.3-2.0)	<0.001
April-July	56.7 (1368/2412)	1.4 (1.1-1.7)	0.001
August-December	48.8 (240/492)	1	

Note: OR: odds ratio; CI: confidence interval; p: probability; SLS: second litter syndrome.

Table 3. Multivariable analysis for risk factors of second litter syndrome in 3957 Landrace×Yorkshire sows

Variables	Model 1 (OR, 95%CI)	Model 2 (OR, 95%CI)	p
Number of piglets born alive in first parity	2.3 (2.2-2.4)		<0.001
Age at first insemination post-weaning			
344-400 days	1.8 (1.3-2.5)		0.001
400-420 days	1.9 (1.4-2.6)		<0.001
420-440 days	1.4 (1.0-2.0)		0.038
440-470 days	1.3 (0.9-1.9)		0.149
>470 days	1		
Litter size at weaning			
<11 piglets		1	
11 piglets		1.5 (1.1-1.9)	<0.001
12 piglets		1.9 (1.5-2.4)	<0.001
13 piglets		2.2 (1.7-2.7)	<0.001
14-19 piglets		3.1 (2.3-3.8)	<0.001
Weaning to service interval			
0-6 days		1.4 (1.1-1.6)	<0.001
7-10 days		1.3 (1.1-1.7)	0.009
11-17 days		1.3 (0.9-1.9)	0.161
>17 days		1	
Month of first insemination post-weaning			
December-April		1.7 (1.3-2.2)	<0.001
May-August		1	
September-November		2.1 (1.6-2.7)	<0.001

Note: OR: odds ratio; CI: confidence interval; p: probability.

higher odds of SLS compared with those bred after >17 days.

In terms of seasonality, the inseminations conducted in December-April (OR=1.7, 95% CI: 1.3-2.2, p<0.001) and September-November (OR=2.1, 95% CI: 1.6-2.7, p<0.001) were associated with higher odds of SLS compared with May-August (Table 3).

DISCUSSION

The incidence of SLS in the present study was 56.8%, which is comparable to the 56.6% reported in Spain (Sanz-Fernández *et al*., 2022). However, it was higher than 48.1% in Mexico (Segura-Correa *et al*., 2014), 47.8% in Vietnam (Nam *et al*., 2024b), and 33.3% in the Netherlands (Sell-Kubiak *et al*., 2021). These differences may reflect variations in genetics, management practices, and environmental conditions across production systems.

The positive association between NBA1 and SLS observed in the present study aligns with previous reports (Morrow *et al*., 1992; Segura Correa *et al*., 2013; Segura-Correa *et al*., 2014; Sanz-Fernández *et al*., 2022). Specifically, compared with sows that had NBA1<9 piglets, those with NBA1=9-10, 11-12, and >12 piglets had increased odds of SLS, with ORs of 3.6, 9.5, and 33.2, respectively (Segura Correa *et al*., 2013). NBA has been shown to be positively associated with piglet birth weight (Nam & Peerapol, 2020; Nam & Sukon, 2021; Lanh & Nam, 2022; Junior *et al*., 2023). Furthermore, sows with moderate body condition scores produced larger NBA compared with those with low or high scores (Ajay *et al*., 2023; Authement & Knauer, 2023). The associations between NBA and piglet birth weights, as well as sow body condition score, suggest that careful management of sows with large NBA1 through optimizing body condition after weaning and improving piglet birth weight may increase NBA in the second parity and consequently reduce the risk of SLS.

The effect of ASAI on SLS in this study is consistent with Sanz-Fernandez *et al*. (2022), who showed that sows with an average AFF of 337 days lost twice as many piglets in the second litter compared to those with an average AFF of 474 days. In contrast, Sell-Kubiak *et al*. (2021) reported no effect of AFAI on SLS. As primiparous sows are usually not fully mature at the time of their second insemination (Dumniem *et al*., 2025), a higher ASAI provides additional time for development, which contributes to a greater NBA in the second litter and a lower risk of SLS (Morrow *et al*., 1992).

This study is among the first to report a negative association between LSW/LWW and SLS in Landrace×Yorkshire sows raised under tropical conditions. Previous studies have shown that smaller LSW improves the quality and survival rates of embryos (Weaver *et al*., 2024a; Weaver *et al*., 2024b). In contrast, a larger LSW increases lactational weight loss (Guo *et al*., 2019) and impairs post-weaning follicular development (Liu *et al*., 2025). These findings suggest that sows producing higher LSW/LWW are more likely to experience greater body reserve depletion, which could impair embryo quality and reduce NBA in the subsequent litter, or increase the risk of SLS. Practically, these findings suggest a need to control LSW and adjust nutritional management to reduce excessive lactational body weight loss. Future research should investigate suitable levels of LSW and nutritional strategies that promote body reserve recovery and maintain reproductive efficiency in primiparous sows reared in tropical environments.

The lowest odds of SLS found in sows with WSI >17 days in the present study are consistent with the findings of Segura-Correa *et al*. (2014). Previous research has reported that shorter intervals of WSI, such as WSI <22 days (Morrow *et al*., 1992), <12 days (Segura Correa *et al*., 2013), or <21 days (Hoving *et al*., 2010), increased the risk of SLS. This relationship may be partly due to the longer recovery time available to sows with extended WSI (>17 days), which allows them to regain body reserve and achieve better reproductive performance in the next cycle (Hoving *et al*., 2010). Nevertheless, the higher odds of SLS observed in sows with WSI of 0-6 days are difficult to explain, as this short interval has been shown to be associated with favorable outcomes such as higher farrowing rates and larger litter sizes compared to longer WSIs (Hoshino & Koketsu, 2008; Nam & Sukon, 2024).

The effect of season on SLS appears inconsistent, as Segura-Correa *et al*. (2013) reported a slightly higher risk during the rainy (OR=1.20) and dry seasons (OR=1.24) compared with the windy season, whereas other studies found no significant association between season and SLS (Segura-Correa *et al*., 2014; Sell-Kubiak *et al*., 2021). In this study, the lower incidence of SLS in sows inseminated between May and August and those farrowing between August and December is likely the result of multiple interacting factors. Seasonal variation in NBA2 may partly explain this pattern, as higher NBA in autumn and winter compared with summer and spring has been reported (Piñán *et al*., 2021), along with increased litter size in winter relative to summer (Chokoe & Siebrits, 2009). In the present study, NBA2 of sows inseminated between May and August (12.7) and those farrowing between August and December (12.6) were higher than those of sows inseminated during September-November (12.4) and farrowing during January-March (12.4), respectively. However, the lower SLS incidence may also be related to their smaller NBA1 (12.5) values compared to the NBA1 values in other groups, which ranged from 12.6 to 12.9. These findings suggest that the seasonal variation in SLS incidence is influenced not only by seasonal changes in NBA2 but also by the baseline established by NBA1 in the first parity. Therefore, breeding schedules should be planned to align farrowings with favorable periods, and special attention should be given to sows with a large NBA1, as they may require additional management strategies, such as optimized nutrition or extended recovery time, to reduce metabolic stress and minimize the likelihood of SLS in subsequent parities.

In the present study, LL did not affect the incidence of SLS, which aligns with the findings of Segura-Correa *et al*. (2013). In contrast, Sell-Kubiak *et al*. (2021) reported that a longer LL decreased the risk of SLS, and Sanz-Fernandez *et al*. (2022) observed that a very short LL (15.8 days) reduced NBA2 compared with a longer LL (>21.7 days). The discrepancies among the studies could be attributable to variations in genetic background, management practices, and environmental conditions. Based on the present findings, extending LL does not appear to reduce the incidence of SLS.

This study has some limitations. First, because information on body condition score and body weight loss during lactation was not available, it was impossible to assess the impact of energy balance on the risk of SLS. Second, this study did not measure hormonal profiles or indicators of follicular and oocyte quality/quantity, which restricted the ability to explore the underlying physiological mechanisms. These limitations should be taken into account when interpreting the results, highlighting the need for future studies that incorporate both metabolic and reproductive biomarkers.

CONCLUSION

This study indicated that the incidence of SLS in Landrace × Yorkshire sows under tropical conditions was high. Major risk factors included large NBA1, short WSI, high LSW, and low ASAI, while insemination in May-August and farrowing in August-December reduced the risk. These findings suggest that optimizing recovery intervals, managing litter size at weaning, and adjusting breeding schedules to favorable seasons can help reduce SLS if productivity trade-offs are carefully balanced.

CONFLICT OF INTEREST

We certify that there is no conflict of interest arising from any financial, personal, or other relationships with individuals or organizations related to the material discussed in the manuscript.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used ChatGPT to improve readability and language. The authors have reviewed and edited the content as needed and take full responsibility for the publication.

REFERENCES

Ailobhio, D. T., & Ikughur, J. A. (2024). A review of some goodness-of-fit tests for logistic regression model. Asian Journal of Probability and Statistics, 26(7), 75–85. https://doi.org/10.9734/ajpas/2024/v26i7631

Ajay, A., Chauhan, A., Vaishnav, S., Rani, C., Kumar, B., De, U. K., Verma, M. R., Singh, M., & Gaur, G. K. (2023). Impact of body condition on sow and litter performance, postpartum physiological, hematological, and biochemical parameters in Landlly crossbred pigs. Tropical Animal Health Production, 55(6), 393. https://doi.org/10.1007/s11250-023-03772-4

Authement, M. R., & Knauer, M. T. (2023). Associations between sow body condition with subsequent reproductive performance. Open Journal of Animal Sciences, 13(3), 310-322. https://doi.org/10.4236/ojas.2023.133023

Buthelezi N. L., Mtileni B., Nephawe K. A., Modiba M. C., Mpedi H., Idowu P. A., & Mpofu, T. J. (2024). Effects of parity, season of birth, and sex on within-litter variation and pre-weaning performance of F1 Large White × Landrace pigs. Veterinary World, 17(7), 1459-1468. https://doi.org/10.14202/vetworld.2024.1459-1468

Chokoe, T., & Siebrits, F. (2009). Effects of season and regulated photoperiod on the reproductive performance of sows. South African Journal of Animal Science, 39(1), 45-54. https://doi.org/10.4314/sajas.v39i1.43545

Dey, D., Haque, M. S., Islam, M. M., Aishi, U. I., Shammy, S. S., Mayen, M. S. A., Noor, S. T. A., & Uddin, M. J. (2025). The proper application of logistic regression model in complex survey data: a systematic review. BMC Medical Research Methodology, 25(1), 15. https://doi.org/10.1186/s12874-024-02454-5

Dumniem, N., Parsons, T. D., & Tummaruk, P. (2025). Feeding levels during early gestation in a group-housing system for primiparous sows: impact on piglet birthweight and litter uniformity. Animal Bioscience, 38(2), 360-370. https://doi.org/10.5713/ab.24.0415

Estrada J., Johnson D. C., Kyle K. L., Perez J., Parr E., Welch M. W., Neill C., Peterson B. A., & Boler. D. D. (2024). Characterizing sow feed intake during lactation to explain litter and subsequent farrowing performance. Journal of Animal Science, 102, skae093. https://doi.org/10.1093/jas/skae093

Fenlon, C., O'Grady, L., Doherty, M. L., & Dunnion, J. (2018). A discussion of calibration techniques for evaluating binary and categorical predictive models. Preventive Veterinary Medicine, 149, 107-114. https://doi.org/10.1016/j.prevetmed.2017.11.018

Gruhot, T. R., Calderón Díaz, J. A., Baas, T. J., & Stalder, K. J. (2017). Using first and second parity number born alive information to estimate later reproductive performance in sows. Livestock Science, 196, 22-27. https://doi.org/10.1016/j.livsci.2016.12.009

Guo, J. Y., Sun, Y., DeDecker, A. E., Coffey, M. T., & Kim, S. W. (2019). Effect of suckling intensity of primiparous sows on production performance during current and subsequent parities. Journal of Animal Science, 97(12), 4845-4854. https://doi.org/10.1093/jas/skz341

Hoshino, Y., & Koketsu, Y. (2008). A repeatability assessment of sows mated 4–6 days after weaning in breeding herds. Animal Reproduction Science, 108(1-2), 22-28. https://doi.org/10.1016/j.anireprosci.2007.06.029

Hoving, L. L., Soede, N. M., Graat, E. A., Feitsma, H., & Kemp, B. (2010). Effect of live weight development and reproduction in first parity on reproductive performance of second parity sows. Animal Reproduction Science, 122(1-2), 82-89. https://doi.org/10.1016/j.anireprosci.2010.07.009

Hoving, L. L., Soede, N. M., Graat, E. A. M., Feitsma, H., & Kemp, B. (2011). Reproductive performance of second parity sows: Relations with subsequent reproduction. Livestock Science, 140(1-3), 124-130. https://doi.org/10.1016/j.livsci.2011.02.019

Huang, Y., Li, W., Macheret, F., Gabriel, R. A., & Ohno-Machado, L. (2020). A tutorial on calibration measurements and calibration models for clinical prediction models. Journal of the American Medical Informatics Association, 27(4), 621-633. https://doi.org/10.1093/jamia/ocz228

Ju M., Wang X., Li X., Zhang M., Shi L., Hu P., Zhang B., Han X., Wang K., Li X., Zhou L., & Qiao, R. (2022). Effects of litter size and parity on farrowing duration of Landrace × Yorkshire sows. Animals, 12(1), 94. https://doi.org/10.3390/ani12010094

Junior, V., Rosa, E., Fagundes, D., Peripolli, V., Ulguim, R., Siqueira, B., Messias, H., Bortolozzo, F., & Bianchi, I. (2023). Risk factors associated with stillbirth in sows. Ciência Rural, 53(11), e20220080. https://doi.org/10.1590/0103-8478cr20220080

Kim, J. H. (2019). Multicollinearity and misleading statistical results. Korean Journal of Anesthesiology, 72(6), 558-569. https://doi.org/10.4097/kja.19087

Lanh, D. T. K., & Nam, N. H. (2022). High stillbirth rate in a swine farm in Vietnam and associated risk factors. Journal of Advanced Veterinary and Animal Research, 9(1), 13-18. https://doi.org/10.5455/javar.2022.i564

Liu, K., Zhang, L., Xu, X., Song, M., Ding, H., Xiao, L., Wen, J., Zhou, C., Bai, J., & Liu, Y. (2025). Lactational high weight loss impairs follicular development by causing mitochondrial dysfunction of ovarian cells in sows and mitigated by butyrate supplement. Journal of Advanced Research 2025, S2090-1232(25)00069-4 https://doi.org/10.1016/j.jare.2025.01.050

Morrow, W. E. M, Leman, A. D., Williamson, N. B., Morrison, R. B., & Ashley Robinson, R. (1992). An epidemiological investigation of reduced second-litter size in swine. Preventive Veterinary Medicine, 12(1-2), 15-26. https://doi.org/10.1016/0167-5877(92)90065-N

Nam, N., Lanh, D., Thanh, N., Dung, B., & Sukon, P. (2025). Determinants of prolonged weaning-to-service interval in primiparous Landrace × Yorkshire sows under tropical conditions: Impact of age at first farrowing, lactation length, and litter size at weaning. Veterinary World, 18(7), 2031-2038. https://doi.org/10.14202/vetworld.2025.2031-2038

Nam, N. H., & Sukon, P. (2024). Mutual relationship between litter size and weaning to first service interval in the sow. International Journal of Veterinary Science, 12(5), 672-675. https://doi.org/10.47278/journal.ijvs/2023.043

Nam, N. H., Khoudphaithoune, T., Lanh, D. T. K., Thanh, N. V., Truong, N. D., Toan, N. C., Dung, B. V., Dao, B. T. A., & Sukon, P. (2024a). Effects of second litter syndrome on reproductive performance in sows. Veterinary World, 17(8), 1680-1684. https://doi.org/10.14202/vetworld.2024.1680-1684

Nam, N. H., Khoudphaithoune, T., Lanh D. T. K., Thanh, N. V., Truong, N. D., Toan, N. C., Dung, B. V., Dao, B. T. A., & Sukon, P. (2024b). Effects of parity number on some reproductive parameters in Landrace x Yorkshire sows. International Journal of Veterinary Science, 13(5), 712-716. https://doi.org/10.47278/journal.ijvs/2024.164

Nam, N. H., & Sukon, P. (2021). Non-infectious risk factors for intrapartum stillbirth in a swine farm in the North of Vietnam. Veterinary World, 14(7) 1829-1834. https://doi.org/10.14202/vetworld.2021.1829-1834

Nam, N. H., & Sukon, P. (2020). Risk factors associated with stillbirth of piglets born from oxytocin-assisted parturitions. Veterinary World 13(10), 2172-2177. https://doi.org/10.14202/vetworld.2020.2172-2177

Piñán, J., Alegre, B., Kirkwood, R. N., Soriano-Úbeda, C., Maj, M., Domínguez, J. C., Manjarín, R., & Martínez-Pastor, F. (2021). Effect of season and parity on reproduction performance of iberian sows bred with duroc semen. Animals, 11(11), 3275. https://doi.org/10.3390/ani11113275

Rabelo, S. S., Faria, B. G., Rocha, L. G. P., Fereira, B. A. P., Chaves, B. R., Pontelo, T. P., Pereira, L. J., & Zangeronimo, M. G. (2016). Incidence of the second parity syndrome in sows from a commercial farm. Arquivo Brasileiro de Medicina Veterinaria e Zootecnia, 68(04), 1085-1089. https://doi.org/10.1590/1678-4162-8651

Saito, H., Sasaki, Y., Hoshino, Y., & Koketsu, Y. (2010). The occurrence of decreased numbers of pigs born alive in parity 2 sows does not negatively affect herd productivity in Japan. Livestock Science, 128(1-3), 189-192. https://doi.org/10.1016/j.livsci.2009.10.014

Sanz-Fernández, S., Díaz-Gaona, C., Casas-Rosal, J. C., Quintanilla, R., López, P., Alòs, N., & Rodríguez-Estévez, V. (2022). Second litter syndrome in Iberian pig breed: factors influencing the performance. Animal, 16(12), 100675. https://doi.org/10.1016/j.animal.2022.100675

Segura-Correa, J. C., Magaña-Monforte, J. G., Aké-López, R., & Herrera-Camacho, J. (2014). Risk factors affecting the drop of litter size at second parity in sows in la piedad michoacan, Mexico. Animal Science and Biotechnologies, 47(1), 281-285.

Segura Correa, J. C., Alzina-López, A., & Santos-Ricalde, R. H. (2013). Risk factors associated with the occurrence of the second-litter syndrome in sows in southeastern Mexico. The Scientific World Journal, 2013(1), 969620. https://doi.org/10.1155/2013/969620

Sell-Kubiak, E., Knol, E. F., Mulder, H. A., & Pszczola, M. (2021). Unraveling the actual background of second litter syndrome in pigs: based on Large White data. Animal, 15(2), 100033. https://doi.org/10.1016/j.animal.2020.100033

Steyerberg, E. W. (2019). Clinical prediction models. A practical approach to development, validation and updating. Second edition. Springer, New York. https://doi.org/10.1007/978-3-030-16399-0

Thomas L. L., Goodband R. D., Tokach M. D., Woodworth J. C., DeRouchey J. M., & Dritz, S. S. (2018). Effect of parity and stage of gestation on growth and feed efficiency of gestating sows. Journal of Animal Science, 96(10), 4327-4338. https://doi.org/10.1093/jas/sky279

Vargovic L., Harper J.A., & Bunter, K. L. (2022). Traits defining sow lifetime maternal performance. Animals, 12(18), 2451. https://doi.org/10.3390/ani12182451

Weaver, A. C., Kind, K. L., Herde, P. J., & van Wettere, W. H. E. J. (2024a). Split weaning improves pregnancy rate and embryo survival in sows mated in lactation. Animal Reproduction Science, 263, 107440. https://doi.org/10.1016/j.anireprosci.2024.107440

Weaver, A. C., Kind, K. L., Kelly, J. M., Herde, P., & van Wettere, W. H. E. J. (2024b). Effect of split weaning on follicle development and oocyte quality in multiparous sows. Animal Reproduction Science, 262, 107434. https://doi.org/10.1016/j.anireprosci.2024.107434

Xi, W. F., Jiang, Q. W., & Yang, A. M. (2024). Using stepwise regression to address multicollinearity is not appropriate. International Journal of Surgery, 110(5), 3122-3123. https://doi.org/10.1097/JS9.0000000000001208

Zhang, J., Yang, Y., & Ding, J. (2023). Information criteria for model selection. WIREs Computational Statistics Journal, 15(5), e1607. https://doi.org/10.1002/wics.1607