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Second litter syndrome in Iberian pig breed: factors influencing the performance

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ABSTRACT

Second litter syndrome (**SLS**) consists of a loss of prolificacy in the second parity (**P2**), when a sow presents the same or lower results for litter size than in the first parity (**P1**). This syndrome has been reported for modern prolific breeds but has not been studied for rustic breeds. The objectives of this study are to determine how and to what degree Iberian sows (a low productivity breed recently raised on intensive farms) are affected by SLS; to establish a target and reference levels; and to assess the factors influencing the performance. Analysed data correspond to 66 Spanish farms with a total of 126 140 Iberian sows. The average Iberian sow prolificacy in P1 was 8.91 total born (**TB**) and 8.47 born alive (**BA**) piglets, whereas in P2, it decreased by −0.05 TB and −0.01 BA piglets, suggesting some general incidence of SLS. At the sow level, 56.63% did not improve prolificacy in terms of BA piglets in P2, and 16.98% had a clear decrease in prolificacy, losing ≥3 BA piglets in P2. Within herds, a mean of 57.75% of sows showed SLS, with an evident decrease in the number of BA piglets in P2. The plausible target for the Iberian farm's prolificacy comes from the quartile of farms with the lowest percentage of SLS sows within the farms with the highest prolificacy between P1 and P2 (mean of 8.77 BA). So, in this subset of farms (N = 17), 47.3% of sows improved their prolificacy in P2 (i.e. did not show SLS). Hence, half the sows could be expected to show SLS even on farms with a good performance. Finally, this study brings out the main factors reducing P2 prolificacy through SLS in the Iberian breed: later age at first farrowing, long first lactation length, medium weaning to conception interval and large litter size in P1. In conclusion, improving the reproductive performance of Iberian farms requires reducing the percentage of sows with SLS, paying special attention to those risk factors. The knowledge derived from this study can provide references for comparing and establishing objectives of performance on Iberian sow farms which can be used for other robust breeds.

Implications

Second litter syndrome consists of a loss of prolificacy in the second parity, when a sow presents the same or lower results for litter size than in the first parity. It highly affects the rustic breed studied because half the sows on any farm can be expected to have it, even on those farms with good performance. Improving reproductive performance requires reducing the incidence of this syndrome, paying attention to these risk factors: later age of gilts at first parity, long first lactation length, medium weaning to conception interval and large litter size in first parity.

Introduction

The Iberian pig is an autochthonous and robust porcine breed derived from ancestral domestic pig populations of the Iberian Peninsula (Nieto et al., 2019). Nowadays, this breed is mainly raised on intensive farms. For the first time, Piñeiro et al. (2012) studied the reproductive performance of Iberian sows from eight farms, showing an average prolificacy of 8.29 total born (**TB**) for all parities.

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The study and evaluation of the first parities is a strategy widely used in swine production to determine and predict the lifetime performance of sows (Iida et al., 2015; Gruhot et al., 2017). However, some sows may suffer a problem that causes a decrease in productivity, presenting the same or smaller litter size in second parity (**P2**) regarding first parity (**P1**) (Morrow et al., 1992). This problem is known as "second litter syndrome" (**SLS**).

Different studies have reported SLS in several countries: Sasaki et al. (2011) in Japan, Segura-Correa et al. (2013) in Mexico, Rabelo et al. (2016) in Brazil, and more recently Sell-Kubiak et al. (2021) in Netherlands.

Causes and risk factors of SLS have been reported in highly productive commercial breeds. These factors include age and BW at first insemination, loss of body condition at first lactation, herd size, environmental conditions and season of the year in which parities occur, or the wean-to-oestrus interval (Hoving et al., 2010; Sasaki et al., 2011; Boulot et al., 2013; Segura-Correa et al., 2013; Segura-Correa et al., 2014; Rabelo et al., 2016).

The relevance of characterising this problem in the Iberian breed lies in the great importance of this robust breed as a model for other robust and low prolificacy breeds (i.e., Čandek-Potokar and Nieto Liñán, 2019). The objective of this study is to determine how and to what degree Iberian sows and their farms are affected by SLS, to establish a target and reference levels, and to assess the influence of some risk factors.

Material and methods

Data source

The dataset analysed in the present study (sample population) comes from the BDporc Ibérico databank within the framework of a collaboration agreement between Institute of Agriculture and Food Research and Technology (**IRTA**) and the Department of Animal Production of the University of Cordoba. All the sows included in this study were pure Iberian breed and had completed at least the first two cycles (1st and 2nd parities, abbreviated as P1 and P2). These data corresponded to 66 anonymous farms and a total of 126 140 sows.

Data used of every sow were as follows: farm random number, date of birth, dates of 1st and 2nd fertile mating, dates of 1st and 2nd farrowings, date of 1st weaning, number of piglets born alive (**BA**), stillborn (**SB**) and TB of P1 and P2. Using those data, the following variables were obtained for every sow: age (months) at 1st fertile service, age at 1st farrowing, length of 1st lactation, weaning to conception interval (**WCI**), farrowing to conception interval (**FCI**) and differences in TB and BA between P2 and P1; and sows were classified into three categories of SLS incidence according to these differences:

1. Sows without SLS effect = sows with at least an extra piglet in P2.
2. Sows with a slight SLS effect = sows with the same number of piglets in P2.
3. Sows with a strong SLS effect = sows with fewer piglets in P2.

Data filtering

To avoid errors, before the analysis, a filtering of incomplete and/or erroneous data was carried out.

Following the methodology of previous studies (e.g., Saito et al., 2010; Sasaki et al., 2011), sows with wrong data, extreme outliers and lack of some productive parameters have been filtered as follows:

1. Discarding sows with 0 TB in P1 or P2 or without complete information of either of these two parities (509 sows).
2. Removing sows with outlier prolificacy: sows with a very high TB number in P1 (81 sows). For this filter, 17 piglets were established as the TB limit, discarding those sows with $\geq$18 TB piglets. The breed average of TB of all cycles is 8.2 (IRTA, 2017), and this is 7.55 in P1 (Piñeiro et al., 2012).
3. Removing by age at the 1st fertile service; establishing a lower limit of $\leq$6 months and an upper limit of 16 $\geq$months (96 sows). To establish this limit, it has been taken into account that 5 months is a very early age to reach puberty with boar stimulation and gilts should be mated from the 2nd cycle (with 6.5 months old at the earliest) (Patterson et al., 2014). Besides that, it is recommended to mate Iberian breed gilts at 9–11 months old depending on body condition (Pecero Sayago, 2021).

The number of sows removed by incomplete and/or erroneous data has been 686 sows, giving a final total of 126 140 sows in the study.

Classification into categories

Sows were categorised into groups according to their age at 1st farrowing, 1st lactation length, prolificacy in P1 (number of piglets BA) and WCI, based on the upper 25 percentile. Besides that, sows were classified according to their type of SLS for TB and BA (three categories): sows without SLS effect, sows with a slight SLS effect and sows with a strong SLS effect and difference for TB and BA between P2 and P1 (+1 piglet, +2 piglets, +3 or more piglets, P1 and P2 with the same piglets, −1 piglet, −2 piglets and −3 or more piglets).

Statistical analysis

Data were analysed with IBM SPSS® software.

The whole population of sows was calculated thus: percentage of sows with SLS and percentage of sows of each type of SLS, for both TB and BA; distribution of frequencies and percentage of sows according to the seven groups established of differences for TB and BA between P2 and P1.

Every farm was calculated thus: average of individual sow differences of prolificity between P1 and P2, for both TB and BA; percentage of sows without SLS, with slight SLS and with strong SLS, for both TB and BA.

In addition, to make comparisons between groups, parametric tests were applied, once the normality and homoscedasticity of the variables involved were verified. Specifically, the ANOVA test was done and later the Student–Newman–Keuls or SNK test was performed to analyse the distribution of differences in the groups; different letters have been used (*a*, *b*, *c*, *d*) to indicate significant differences between groups. Finally, for the cases in which the differences were significant, the effect size (η^2) was calculated, which provides a measure of the relevance of the differences found. Cohen (1988) provides benchmarks for effect size classification levels to define small (η^2 = 0.01 to <0.06), medium (η^2 = 0.06 to <0.14), and large ($\eta^2 \geq 0.14$) effects.

Results

Descriptive statistics of reproductive variables affecting productivity in the whole dataset of Iberian sows, as well as differences in prolificacy between P1 and P2, are shown in Table 1. Iberian gilts had their first farrowing at about 13 months of age, with a later mean lactation length of 23.78 days. The average litter size in P1

Table 1
Descriptive statistics of Iberian sows (N = 126 140) productivity and differences between 2nd and 1st parities.

Iberian sows	Mean	Mode	SD	Percentiles		
				25	50	75
1st Farrowing Age	13.26	11.83	1.81	11.73	12.97	14.50
Duration of Lactation (days)	23.78	28.00	6.31	19.00	24.00	28.00
WCI (days)	10.02	5.00	9.38	5.00	6.00	11.00
FCI (days)	33.81	35.00	11.07	7.00	8.00	10.00
TB in P1	8.91	8.00	2.23	7.00	8.00	10.00
BA in P1	8.47	8.00	2.25	7.00	9.00	10.00
TB in P2	8.87	8.00	2.70	7.00	8.00	10.00
BA in P2	8.46	8.00	2.63	7.00	9.00	10.00
DIF TB	−0.04	0.00	2.75	−2.00	0.00	2.00
DIF BA	−0.01	0.00	2.81	−2.00	0.00	2.00

Abbreviations: WCI = weaning to conception interval; FCI = farrowing to conception interval; BA = piglets born alive; TB = piglets total born; P1 = 1st parity; P2 = 2nd parity; DIF = difference between 2nd parity and 1st parity.

was 8.91 and 8.47 piglets TB and BA, respectively. The average prolificacy slightly decreased in P2, with 8.87 and 8.46 piglets TB and BA, which means −0.04 and −0.01 piglets, respectively. These results indicate a certain incidence of SLS regarding the intervals until conception, mean WCI and FCI were 10.02 and 33.81 days, respectively.

Prolificacy differences between the two first parities in Iberian sows

The percentage of Iberian sows showing SLS is around 57% according to either the decrease in BA or in TB piglets in P2 vs P1 (Table 2). Among the sows showing SLS, the most frequent group (16.98% of sows) corresponded to sows with a big drop in prolificacy in P2, losing more than three piglets BA, followed by the group of shows with slight SLS (similar prolificacy in P1 and P2). However, 40.36% of sows lost prolificity in P2, at least one piglet BA.

Prolificacy differences between the two first parities in farms with Iberian sows

The analysis of the incidence of SLS at farm level (Table 3) revealed that within herds 42.25% of sows improved the number of piglets BA in P2, i.e. these did not show SLS. By contrast, the remaining 57.75% of sows showed SLS. A similar pattern was observed when prolificacy was evaluated in terms of the number of piglets TB: only 41.52% of sows showed an increase of TB in P2, whereas 58.48% of sows showed similar or worse results in P2. SLS became a very severe problem on some of the farms, the worst one having 81.1% of sows showing strong SLS (losing $\geq$ 1 piglet BA in P2).

Focusing on the 25% of farms with less incidence of SLS, these had around 46% of sows improving their prolificacy in P2 (46.16% and 45.65% of sows improving piglets TB and BA, respectively).

SLS was also analysed for the 25% of the farms with the highest productivity (N = 17) with a mean of 8.77 piglets BA between P1 and P2 (Table 4). Within this group of farms, the corresponding quartile of farms with a lower percentage of sows showing SLS was $\leq$52.07% for TB and $\leq$52.72% for piglets BA. These can be considered the best farms, with a plausible target prolificacy for the Iberian breed.

Factors affecting second litter syndrome

The following subsections analyse the relationship between different productive parameters and the SLS. However, this syndrome is the result and not the influencing factor of other parameters.

The size of the effect that these productive parameters had on the level of second litter syndrome for TB was calculated, showing that the greatest effect was presented by prolificacy on the first parity (piglets TB and BA in P1), with a medium effect size, with values of η^2 = 0.132 and 0.105, respectively; and the prolificacy on the second cycle (piglets TB and BA in P2), with a large effect size (η^2 = 0.305 and 0.280, respectively). Similar behaviour was found in the size of the effect of the productive parameters on SLS for BA piglets (Table 5).

Comparisons of productive parameters depending on the second litter syndrome level

Basic statistics of different sow productive traits according to the SLS category are shown in Table 5. Results show an association between sow prolificacy in P1 and the incidence of SLS. Sows without SLS had the lowest prolificacy (means of 8.16 piglets TB and 7.56 BA in P1), while those with a strong SLS had the highest prolificacy (means of 9.80 piglets TB and 9.49 BA in P1). The differences in prolificacy between these two groups were significant. The group of sows with strong SLS for BA lost a mean of 2.44 piglets TB and 2.65 BA in P2.

Regarding other productive parameters such as WCI or first farrowing age, which are analysed in the following sections, these did not show an evident association with the SLS categorisation of sows.

Influence of the first farrowing age

The highest prolificacy (9.55 TB) corresponded to the youngest gilts at farrowing (mean age of 11.24 months), while the lowest one (8.32 TB) corresponded to gilts that had their first parity at an older age (mean of 15.80 months) (Table 6). From the youngest quartile of gilts to the oldest one, the prolificacy gradually decreased significantly.

In addition, the youngest gilts at farrowing had the lowest mean WCI (9.47 days), while the two older groups of animals had the worst fertility results, with the highest WCI (10.55 and 10.24 days respectively for Q3 and Q4), with significant differences among the groups.

These results show a direct association between the age of gilts at first farrowing and the SLS incidence. Consistently, the youngest gilts at 1st farrowing had the highest prolificacy in P2 (9.46 TB and 8.97 BA). In addition, the youngest gilts at 1st farrowing showed the highest SLS for TB and BA (with a difference of −0.10 and −0.08, respectively), while the remaining sows had lower SLS incidence, with significant differences between the prolificacy drop of the different categories of age at 1st farrowing (Table 6). The gilts with farrowing at the earliest age (mean of 11.24 months) lost twice as many piglets between P1 and P2 than the sows with farrowing at the oldest age (mean of 15.80 months). Furthermore, in

Table 2
Distribution of frequencies for groups of differences of prolificacy between 2nd and 1st parities in Iberian sows (N = 126 140).

	Piglets total born			Piglets born alive		
Item	N	Percentage	Accumulated percentage	N	Percentage	Accumulated percentage
Sows without SLS						
+1 piglet	19 036	15.09	15.09	19 196	15.22	15.22
+2 piglets	14 806	11.74	26.83	14 594	11.57	26.79
+3 or more piglets	20 231	16.04	42.87	20 921	16.59	43.37
Sows with SLS						
Same number of piglets	20 456	16.22	16.22	20 519	16.27	16.27
−1 piglet	17 172	13.61	29.83	16 984	13.46	29.73
−2 piglets	12 977	10.29	40.12	12 511	9.92	39.65
−3 or more piglets	21 462	17.01	57.13	21 415	16.98	56.63

Abbreviations: SLS = second litter syndrome.

Table 3
Descriptive statistics for the incidence of the second litter syndrome for each farm of Iberian sows (N = 66).

Farms with Iberian sows (N = 66)	Mean	SD	Min	Max	Percentiles		
					25	50	75
Percentage of sows with SLS for total born within farms							
Without SLS	41.52	7.02	15.8	52.5	37.95	41.90	46.16
With slight SLS (sl)	17.31	4.21	8.4	39.7	14.86	16.66	18.44
With strong SLS (st)	41.18	7.87	14.3	75.8	36.67	40.36	44.37
With SLS (sl + st)	58.48	7.02	47.5	84.2	53.84	58.10	62.05
Percentage of sows with SLS for born alive within farms							
Without SLS	42.25	7.06	15.8	56.8	39.00	42.47	45.65
With slight SLS (sl)	17.32	5.04	3.2	44.4	15.28	16.35	18.46
With strong SLS (st)	40.43	8.43	15.9	81.1	35.65	40.19	44.14
With SLS (sl + st)	57.75	7.06	43.2	84.2	54.35	57.53	61.00

Abbreviations: SLS = second litter syndrome; Slight SLS (sl) = same prolificacy in 1st parity and 2nd parity; Strong SLS (st) = prolificacy of 1st parity > prolificacy of 2nd parity.

Table 4
Descriptive statistics for the incidence of the second litter syndrome for the 25% of farms with the highest prolificacy (piglets born alive) within the two first parities (N = 17).

Item	Mean	SD	Min	Max	Percentiles		
					25	50	75
Prolificacy of P1 and P2 (born alive)	8.77	0.62	8.25	10.06	8.28	8.49	9.35
Percentage of sows with SLS for total born within farms with the highest prolificacy between P1 and P2							
Without SLS	42.40	8.46	15.79	52.50	39.42	43.22	47.93
With slight SLS (sl)	15.46	2.53	8.42	18.97	14.32	16.03	17.24
With strong SLS (st)	42.13	9.88	32.35	75.79	35.34	40.16	45.91
With SLS (sl + st)	57.60	8.46	47.50	84.21	52.07	56.78	60.58
Percentage of sows with SLS for born alive within farms with the highest prolificacy between P1 and P2							
Without SLS	45.54	8.57	15.79	55.71	39.94	42.44	47.28
With slight SLS (sl)	15.27	3.59	3.16	20.00	14.70	15.71	17.32
With strong SLS (st)	42.19	11.03	29.05	81.05	36.40	40.73	44.89
With SLS (sl + st)	57.46	8.57	44.29	84.21	52.72	57.56	60.06

Abbreviations: SLS = second litter syndrome; P1 = 1st parity; P2 = 2nd parity; Slight SLS (sl) = same prolificacy in 1st parity and 2nd parity; Strong SLS (st) = prolificacy of 1st partity > prolificacy of 2nd parity.

all cases, the differences were significant and a medium effect size was evident, with respect to the total number of piglets TB in P1.

Influence of the first lactation length

The influence of the 1st lactation length on P2 is evident (Table 7). The highest numbers of TB and BA in P2 (10.14 and 9.60 piglets, respectively) were obtained by the sows with the shortest lactation length in P1 (with a mean of 15.77 days); while the lowest prolificacy corresponds to the quartiles with the longest lactation length (mean $\geq$ 26.28 days), with a mean of $\leq$8.37 TB and 8.02 BA.

The group of sows with the shortest lactation length in P1 had later SLS for TB and BA (−0.26 and −0.23 piglets, respectively); while the intermediate and longest lactation length groups did not show SLS. In all those cases, the differences were significant. In this regard, the prolificacy in P2 (TB and BA) was compared according to the first lactation length with a medium effect size of 0.075 and 0.064 for the number of TB and BA piglets in P2, respectively. In addition, a medium effect size was also observed for the difference in TB between P2 and P1 (η^2 = 0.064).

Influence of prolificacy at first farrowing on the second cycle

The influence of the prolificacy in P1 was directly associated with the prolificacy in P2 (Table 8). The quartile of sows with the highest prolificacy in P1 (mean of 11.51 piglets BA) also had the highest prolificacy in P2 despite having SLS (means of 10.43 piglets TB and 9.89 BA).

Table 5
Mean (SD) of productive parameters according to second litter syndrome category for number of piglets born alive and total born (N = 126 140).

Productive trait	Categories of SLS for piglets total born: Sows without SLS effect	Sows with a slight SLS effect	Sows with a strong SLS effect	Effect size	Categories of SLS for piglets born alive: Sows without SLS effect	Sows with a slight SLS effect	Sows with a strong SLS effect	Effect size
1st farrowing age (months)	13.26ª (1.79)	13.36ᵇ (1.83)	13.23ª (1.83)	0.001***	13.26ª (1.80)	13.37ᵇ (1.83)	13.22ᶜ (1.82)	0.001***
Number of Total born piglets (TB) in P1	8.09ª (1.86)	8.74ᵇ (1.93)	9.85ᶜ (2.32)	0.132***	8.16ª (1.91)	8.73ᵇ (1.94)	9.80ᶜ (2.33)	0.115***
Number of born alive piglets (BA) in P1	7.72ª (1.95)	8.34ᵇ (2.00)	9.31ᶜ (2.34)	0.105***	7.56ª (1.98)	8.39ᵇ (1.84)	9.49ᶜ (2.23)	0.155***
Duration of lactation (days)	23.88ª (6.25)	24.43ᵇ (6.14)	23.42ᶜ (6.42)	0.003***	23.84ª (6.33)	24.54ᵇ (6.13)	23.41ᶜ (6.34)	0.004***
Weaning to conception interval (days)	10.42ª (9.74)	9.89ᵇ (9.26)	9.66ᶜ (9.02)	0.001***	10.43ª (9.80)	9.94ᵇ (9.32)	9.63ᶜ (8.92)	0.002***
Number of total born piglets (TB) in P2	10.48ª (2.28)	8.74ᵇ (1.93)	7.22ᶜ (2.35)	0.305***	10.32ª (2.32)	8.73ᵇ (2.02)	7.36ᶜ (2.47)	0.252***
Number of born alive piglets (BA) in P2	9.96ª (2.24)	8.40ᵇ (1.92)	6.92ᶜ (2.34)	0.280***	10.01ª (2.19)	8.39ᵇ (1.84)	6.84ᶜ (2.33)	0.304***
Difference in TB between P2 and P1	2.39ª (1.52)	0.00ᵇ (0.00)	−2.62ᶜ (1.77)	0.698***	2.16ª (1.76)	0.00ᵇ (0.97)	−2.44ᶜ (2.00)	0.588***
Difference in BA between P2 and P1	2.24ª (1.85)	0.00ᵇ (0.00)	−2.38ᶜ (2.07)	0.566***	2.45ª (1.62)	0.00ᵇ (0.00)	−2.65ᶜ (1.82)	0.688***

Abbreviations: P1 = 1st parity; P2 = 2nd parity; SLS = second litter syndrome.
a–c Values within a row with different superscripts indicate significant differences between groups.
*** $P < 0.01$.

Table 6
Mean (SD) of reproductive parameters related with SLS in the different quartiles of Iberian sows regarding their age at first farrowing (N = 126 140).

Productive trait	Q1	Q2	Q3	Q4	TOTAL	Effect size
1st farrowing age (months)	11.24ª (0.35)	12.26ª (0.35)	13.75ª (0.43)	15.80ª (0.95)	13.26 (1.81)	0.898***
Number of total born piglets (TB) in P1	9.55ª (2.47)	9.30ª (2.52)	8.48ª (1.86)	8.32ª (1.67)	8.91 (2.23)	0.055***
Number of born alive piglets (BA) in P1	9.05ª (2.50)	8.81ª (2.54)	8.09ª (1.91)	7.94ª (1.73)	8.47 (2.25)	0.043***
Number of stillborn piglets in P1	0.51ª (1.01)	0.49ª (0.98)	0.39ª (0.91)	0.37ª (0.85)	0.44 (0.94)	0.004***
Weaning to conception interval (days)	9.47ª (9.01)	9.84ª (9.32)	10.55ª (9.82)	10.24ª (9.33)	10.02 (9.38)	0.002***
Number of total born piglets (TB) in P2	9.46ª (2.95)	9.28ª (2.97)	8.46ª (2.39)	8.27ª (2.22)	8.87 (2.70)	0.036***
Number of born alive piglets (BA) in P2	8.97ª (2.87)	8.84ª (2.88)	8.11ª (2.34)	7.94ª (2.19)	8.47 (2.63)	0.029***
Number of stillborn piglets in P2	0.48ª (0.98)	0.44ª (0.95)	0.35ª (0.84)	0.33ª (0.80)	0.40 (0.90)	0.036***
Difference in TB between P2 and P1	−0.10ª (3.04)	−0.01ª (2.92)	−0.02ª (2.52)	−0.05ª (2.47)	−0.05 (2.75)	0.029***
Difference in BA between P2 and P1	−0.08ª (3.09)	0.04ª (3.00)	0.02ª (2.59)	0.00ª (2.52)	−0.01 (2.81)	0.005***

Abbreviations: P1 = 1st parity; P2 = 2nd parity; Q1 = 25% of youngest sows at 1st farrowing; Q4 = 25% of oldest sows at 1st farrowing.
a–b Values within a row with different superscripts indicate significant differences between groups.
*** $P < 0.01$.

Table 7
Mean (SD) of first lactation length related with the second parity prolificacy and second litter syndrome for Iberian sows (N = 126 140).

Productive trait	Q1	Q2	Q3	Q4	TOTAL	Effect Size
Lactation length (days)	15.77ª (3.49)	21.75ᵇ (1.40)	26.28ᶜ (1.27)	31.33ᵈ (3.49)	23.78 (6.32)	0.825***
Number of total born piglets (TB) in P2	10.14ª (3.07)	8.62ᵇ (2.62)	8.37ᶜ (2.39)	8.34ᶜ (2.24)	8.87 (2.70)	0.075***
Number of born alive piglets (BA) in P2	9.60ª (2.99)	8.24ᵇ (2.56)	8.02ᶜ (2.36)	8.00ᶜ (2.19)	8.47 (2.63)	0.064***
Difference in TB between P2 and P1	−0.26ª (3.34)	0.02ᵇ (2.59)	0.03ᵇ (2.51)	0.02ᵇ (2.44)	−0.05 (2.75)	0.064***
Difference in BA between P2 and P1	−0.23ª (3.40)	0.07ᵇ (2.69)	0.07ᵇ (2.58)	0.07ᵇ (2.47)	−0.01 (2.81)	0.007***

Abbreviations: P1 = 1st parity; P2 = 2nd parity; Q1 = 25% of sows with shortest lactation length at 1st farrowing; Q4 = 25% of sows with longest lactation length at 1st farrowing.
a–d Values within a row with different superscripts indicate significant differences between groups.
*** $P < 0.01$.

Besides this, the sows with the highest prolificacy for BA in P1 were the ones that lost a greater number of piglets in P2, with a mean difference of −1.45 piglets TB and −1.62 BA. By contrast, the quartile of sows with the lowest productivity in P1 (mean of 6.04 piglets BA) had average gains of 1.22 piglets TB and 1.63 BA in P2. In all cases, the differences were significant. Regarding the effect size of the sow prolificacy at first farrowing for BA on the prolificacy of P2, it is shown that there was a medium effect on the number of TB and BA piglets in P2 (values of 0.123 and 0.118, respectively) and on the difference in BA between P2 and P1 (0.123).

Influence of weaning to conception interval on the second cycle prolificacy

The quartile of sows with the shortest WCI (mean of 4.17 days) had the highest prolificacy in P2, with means of 9.59 piglets TB and 9.11 BA. This prolificacy decreased as WCI increased. However, the prolificacy between P1 and P2 slightly improved for the quartile of sows with the highest WCI, with an average gain of 0.24 piglets TB and 0.28 BA. All differences were significant, although the effect size of the differences was small.

Table 8
Mean (SD) of the sows' prolificacy at first farrowing for piglets born alive on the second cycle (N = 126 140).

Productive trait	Quartiles of sows according to the prolificacy in P1					
	Q1 (25% of sows with the highest prolificacy in P1 for piglets BA)	Q2	Q3	Q4 (25% of sows with the lowest prolificacy in P1 for piglets BA)	TOTAL	Effect Size
Number of born alive piglets (BA) in P1	11.51^a (1.53)	8.81^b (0.60)	7.53^c (0.50)	6.04^d (1.06)	8.47 (2.25)	0.798^{***}
Number of total born piglets (TB) in P2	10.43^a (3.04)	8.80^b (2.48)	8.22^c (2.25)	8.01^d (2.27)	8.87 (2.70)	0.123^{***}
Number of born alive piglets (BA) in P2	9.89^a (2.98)	8.43^b (2.45)	7.89^c (2.21)	7.67^d (2.23)	8.47 (2.63)	0.118^{***}
Difference in TB between P2 and P1	-1.45^a (3.00)	-0.31^b (2.51)	0.36^c (2.32)	1.22^d (2.37)	−0.05 (2.75)	0.032^{***}
Difference in BA between P2 and P1	-1.62^a (2.97)	-0.39^b (2.47)	0.35^c (2.25)	1.63^d (2.46)	−0.01 (2.81)	0.123^{***}

Abbreviations: P1 = 1st parity; P2 = 2nd parity.
[a–d]Values within a row with different superscripts indicate significant differences between groups.
*** $P < 0.01$.

Discussion

The Iberian breed has low prolificacy, with 8.91 piglets TB and 8.47 BA in P1, and 8.87 TB and 8.46 BA in P2. However, it has had an improvement of prolificacy over the last decade if it is compared with the previous average prolificacy of 7.55 TB in P1 and 7.98 in P2 reported by Piñeiro et al. (2012). However, its current performance in P2 shows a clear SLS; which was not evident in that previous study. Thus, the differences of mean productivities between P1 and P2 were −0.5 TB and −0.1 BA piglets for the sows. The current figures for piglets TB and BA, and also the difference in productivity between P1 and P2, are close to that indicated by Noguera et al. (2019) in a study of 3800 Iberian sows of three varieties of this breed.

Most of the previous authors refer to SLS according to BA losses (Morrow et al., 1992; Saito et al., 2010; Sasaki et al., 2011; Segura-Correa et al., 2013; Sell-Kubiak et al., 2021). In the present research, losses or differences between P1 and P2 are similar for TB and BA; hence, the number of piglets BA is sufficient to evaluate SLS.

According to the ideal sow herd parity structure, 16–19% of the breeding sows of a modern farm are second cycle sows (Casanovas, 2008; Houška, 2009; Soede et al., 2013); and 20% were reported for Iberian sows by Aparicio et al. (2011). Although this percentage is conditioned by the culling rate, it is essential to get the maximum efficiency in these animals in order to achieve the maximum possible productivity on the farm, because the performance of the two first parities has a great impact on the future production of the sow, affecting the rest of the parities and, therefore, determining the productive life of the sow (Hoving et al., 2011). Therefore, in future studies, the impact of SLS on sow's lifetime production should be considered.

Hence, SLS is a problem of productivity and 56.63% of Iberian sows have SLS for BA piglets (16.27% have slight SLS for BA and 40.36% of sows lose prolificity in P2, at least one piglet). These values are above the percentage found by other authors for modern sows; for example: Segura-Correa et al. (2014) in a study for a commercial herd of different crossbreds in Mexico, 35.2% of the sows lost at least one piglet in P2, 12.9% had the same prolificacy and 51.9% had at least one piglet more in P2; Saito et al. (2010) and Sasaki et al. (2011) reported that 38.1 and 49.5% of the sows studied, respectively, had at least one piglet less in P2 in Japanese commercial herds of crossbreds of Landrace and Large White; and Sell-Kubiak et al. (2021) showed 33.32% in a study of Large white sows in Netherlands. However, the current results for Iberian sows with SLS are similar to the figures shown by Morrow et al. (1992) and Segura-Correa et al. (2013) with 54 and 55.8% of sows of different breeds, respectively. Although the latter authors found similar SLS percentages to the present study, the high percentage of Iberian sows with SLS could be explained as a breed effect; because this is a non-improved breed, which has been raised under intensive conditions for several years (Robledo et al., 2007).

The most frequent group of Iberian sows for BA losses is sows with a loss of ≥3 piglets (16.98% of sows); which is indicative of the severity of the problem for this breed at the moment. What is more, 25% of the worst farms, those with the highest SLS, lost a mean of −0.26 piglets TB and −0.24 BA in P2. By contrast, 25% of the best farms, with the lowest SLS, gained 0.21 piglets TB and 0.25 BA in P2. Although both figures are very similar, one refers to gain and the other refers to loss of prolificacy; therefore, the gap is ≥0.47 piglets and the piglet losses on the worst farms are higher than the gains on the best ones for both TB and BA.

Several authors indicate that sows, which have better prolificacy in P2 than in P1 (those without SLS) and also a greater number of piglets BA in their first two parities, go on to be the most productive and the ones that will have a longer lifetime (Sasaki and Koketsu, 2008; Ek-Mex et al., 2016). Hence, for that future life performance and to avoid losses, it is very important to solve the problem of SLS. However, only a mean of 42.25% of the sows on the farms studied improved BA in P2; moreover, the best result for SLS, which correspond to the 25% of farms with the lowest number of sows with SLS, was ≥45.65% of sows without the syndrome for piglets BA. Therefore, this would be the current target. What is more, considering the quartile with the lowest percentage of sows with SLS on the farms with the highest prolificacy for the first two parities (mean of 8.77 piglets BA), the target should be ≥47.28% of sows without SLS. Hence, half of the sows can be expected to show SLS even on farms with good performance.

Therefore, SLS is a handicap for a better performance, but it is not incompatible with a high productivity; for example, the farm with the highest productivity for the two first parities had around 58% of sows with SLS.

The influence of P1 prolificacy in SLS is obvious in the present study, hence, higher prolificacy in P1, for both TB and BA, lower prolificacy in P2; which means higher SLS. However, the quartile of sows with the highest prolificacy in P1 (mean of 11.51 BA piglets) was still those that also had the highest prolificacy in P2 (means of 10.43 TB and 9.89 BA piglets). This relation has already been shown by Koketsu and Iida (2020), who indicate that the number of BA piglets in P1 is an early predictor of sow prolificacy. However, this higher prolificacy in P1 becomes one of the SLS main underlying factors, instead of being a greater opportunity to improve productivity in the following cycles (Iida and Koketsu, 2015). By contrast, the quartile of sows with the lowest productivity in P1 (mean of 6.04 piglets BA) had an average gain of 1.22 TB and 1.63 BA in P2.

The youngest gilts at P1 showed the largest SLS for TB and BA; while the remaining sows (older ones at P1) had a lower SLS, with significant differences. The gilts with farrowing at the earliest age (mean of 11.24 months) lost twice the number of piglets TB and BA than older sows. Hence, 1st farrowing age is directly associated with SLS. The influence of age at first farrowing on the SLS has already been reported in improved breeds (Hoving et al., 2010; Segura-Correa et al., 2013). Furthermore, the SLS problem has often been explained as a consequence of the insufficient development of the sow before the first lactation (Clowes et al., 2003b) or excessive loss of body condition and weight during the first lactation of the sow (Kummer et al., 2006; Schenkel et al., 2010; Soede et al., 2013). However, this group of the youngest gilts had the highest prolificacy, which is the main factor for SLS.

Besides that, the influence of the 1st lactation length in P2 prolificacy has been proven in the current research for Iberian sows; so, the highest numbers of TB and BA in P2 (10.14 and 9.60 piglets, respectively) were obtained by the sows with the shortest lactation length in P1 (mean of 15.77 days), while the lowest prolificacy corresponded to the sows with the longest lactation length (with mean $\geq$26.28 days). However, it has been indicated that a short lactation duration negatively influences the prolificacy of the next cycle (Koketsu and Dial, 1997; Willis et al., 2003), Le Cozier et al. (1997) recommend lactations longer than 21 days, and other authors indicate that an improvement in performance can only be expected by increasing the lactation length (Lawlor and Lynch, 2007). Nevertheless, in the case of the Iberian breed, the sows with the shortest lactation duration turn out to be the most prolific in P2, although these sows showed SLS. In this regard, it is necessary to consider that a shorter lactation length is associated with a lower loss of body condition, and this fact could explain the higher prolificacy. Accordingly, Eissen et al. (2003) and Thaker and Bilkei (2005) focused on the effect of backfat losses and not on protein and fat mass losses, although protein mass losses during lactation negatively affect follicular development (Clowes et al., 2003a) and subsequent prolificacy. Therefore, it would be necessary to reach a balance between lactation length and body condition loss, which has not been explored in the present study, to determine the optimal lactation length for Iberian sows. Nevertheless, it should be noted that in Spain, according to the COUNCIL DIRECTIVE 2008/120/EC concerning minimum standards for the protection of pigs, the routine weaning of piglets under the age of 21 days is not allowed (European Council, 2008).

The comparisons of other productive parameters depending on the SLS level show that the earlier the WCI, the higher the level of SLS for both, TB and BA in P2 for Iberian sows. However, it is well known that a short WCI has a positive influence on subsequent litter size in other breed sows (Koketsu and Dial, 1997; Le Cozier et al., 1997). In this regard, the quartile of sows with the shortest WCI (4.17 days of mean) had the highest prolificacy in P2. This prolificacy decreased as WCI increased. However, the prolificacy between P1 and P2 slightly improved for sows with the longest WCI, because these sows would have had more time to recover from the previous farrowing and lactation (Le Cozier et al., 1997).

Furthermore, WCI and FCI are the result of the quality of artificial insemination and other management practices, and are not primarily caused by the sows themselves. Hence, the effect of the stockmen management could reduce somewhat the incidence of SLS. In this sense, other authors attribute the differences in the incidence of SLS between farms to variations in management and biosecurity measures (Segura-Correa et al., 2013). What is more, it is difficult to analyse and reduce the effects of SLS without working on the feeding of sows during the first lactation period.

Finally, according to Lucia et al. (2000), in a study of 28 herds, culls attributed to "litter performance" constituted 20.6% of all removals of these commercial farms and almost 55% of these culls were sows having 0–2 parities. This fact indicates how necessary it is to reduce the percentage of sows with SLS in any farm; not only for the net increase of piglets in P2, but also for the longer permanence of sows on farms (necessary for their amortisation) and the consequent greater benefit per animal by increasing its lifetime and life number of BA. In addition, this early culling is an animal welfare concern and a sustainability problem because it increases the pork carbon footprint.

Conclusions

These results show an overall different reproductive performance of Iberian sows with other breeds. Nevertheless, SLS is also a serious problem for Iberian sows; it affects the majority of farms and occurs in a percentage of sows higher than has been described for other breeds.

To improve the farms' performance, the percentage of sows with SLS must be reduced, especially those with strong SLS (losing $\geq$ 1 piglet). However, although it is possible to have high productivity despite the existence of this syndrome, it is suggested to achieve the target percentage of $\geq$46% of sows without SLS.

It would be interesting to carry on studying the fertility performance in the third litter and evaluate, the repercussion of SLS on the later performance of the Iberian sows in a future study. Thereby, it is determined that Iberian sows with the highest prolificacy in P1 have the highest prolificacy in P2, despite having SLS. Besides that, prolificacy in P1, which should be an opportunity to improve productivity in the following cycles, becomes one of the SLS main factors; on the contrary, sows with small litters are the least affected by SLS. Other important factors that affect prolificacy in P2 and involve the SLS are those deriving from management: an early age at first farrowing (early mating), lactation length, large litter size in P1 and intermediate WCI. It would be necessary to determine the optimal lactation length for Iberian sows to reach a balance between farrowing recovery and body condition loss, which has not been explored in the present study.

The frequency of SLS within the herds should be lowered by breeding, as other researchers suggest, by putting more selection pressure on increasing litter size in P2.

In addition, to improve the results of this study, it would be necessary to have data about the feeding of sows during lactation, in order to establish clear criteria that help farmers to maintain an adequate sow's body condition during lactation to reduce the SLS; on the other hand, it would also be necessary to have information about variables such as farrowing rate and piglet index for a more exhaustive evaluation of the SLS.

Finally, the knowledge derived from these data should be used to compare and to establish objectives of performance on Iberian sow farms and other rustic breeds.

Ethics approval

Not applicable.

Data and model availability statement.

These data are not deposited in an official repository. The data that support the study findings are confidential.

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Declaration of interest

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References

Aparicio, M, Piñeiro, C, Rodríguez-Estévez, V., 2011. Datos reproductivos del cerdo ibérico: La estructura censal. Retrieved on 23 June 2022, from https://www.3tres3iberico.com/buscando/datos-reproductivos-del-cerdo-iberico-la-estructura-censal_342/.
Boulot, S., Despres, Y., Badouard, B., Sallé, E., 2013. Le «syndrome de 2ème portée» dans les élevages français: prévalence de différents profils et facteurs de risque. Journées Recherche Porcine 45, 79–80.
Čandek-Potokar, M., Nieto Liñán, R.M. (Eds.), 2019. Analytical Review of Productive Performance of Local Pig Breeds. InTechOpen, London, UK.
Casanovas, C., 2008. Estructura del censo (I). Retrieved on 23 June 2022, from https://www.3tres3.com/articulos/estructura-del-censo-i_4261/.
Clowes, E.J., Aherne, F.X., Foxcroft, G.R., Baracos, V.E., 2003a. Selective protein loss in lactating sows is associated with reduced litter growth and ovarian function. Journal of Animal Science 81, 753–764.
Clowes, E.J., Aherne, F.X., Schaefer, A.L., Foxcroft, G.R., Baracos, V.E., 2003b. Parturition body size and body protein loss during lactation influence performance during lactation and ovarian function at weaning in first-parity sows. Journal of Animal Science 81, 1517–1528.
Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. Routledge Academic, New York, NY, USA.
European Council, 2008. Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs. Official Journal of the European Union 47, 5–13.
Eissen, J.J., Apeldoorn, E.J., Kanis, E., Verstegen, M.W.A., de Greef, K.H., 2003. The importance of a high feed intake during lactation of primiparous sows nursing large litters. Journal of Animal Science 81, 594–603.
Ek-Mex, J.E., Segura-Correa, J.C., Alzina-López, A., 2016. Efecto de la reducción o incremento del número de cerdos nacidos vivos en el segundo parto en la vida productiva de las cerdas en el sureste de México. Archivos de medicina veterinaria 48, 243–246.
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.
Houška, L., 2009. The relationship between culling rate, herd structure and production efficiency in a pig nucleus herd. Czech Journal of Animal Science 54, 365–375.
Hoving, L.L., Soede, N.M., Graat, E.A.M., 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, 82–89.
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, 124–130.
Iida, R., Koketsu, Y., 2015. Number of pigs born alive in parity 1 sows associated with lifetime performance and removal hazard in high- or low-performing herds in Japan. Preventive Veterinary Medicine 121, 108–114.
Iida, R., Piñeiro, C., Koketsu, Y., 2015. High lifetime and reproductive performance of sows on southern European Union commercial farms can be predicted by high numbers of pigs born alive in parity one. Journal of Animal Science 93, 2501–2508.
IRTA, 2017. Resultados BDporc-i en 2016. IRTA. Retrieved on 23 June 2022, from https://www.3tres3iberico.com/buscando/resultados-bdporc-i-en-2016_1267/.
Koketsu, Y., Dial, G.D., 1997. Factors influencing the postweaning reproductive performance of sows on commercial farms. Theriogenology 47, 1445–1461.
Koketsu, Y., Iida, R., 2020. Farm data analysis for lifetime performance components of sows and their predictors in breeding herds. Porcine Health Management 6, 24.
Kummer, R., Bernardi, M.L., Wentz, I., Bortolozzo, F.P., 2006. Reproductive performance of high growth rate gilts inseminated at an early age. Animal Reproduction Science 96, 47–53.
Lawlor, P.G., Lynch, P.B., 2007. A review of factors influencing litter size in Irish sows. Irish Veterinary Journal 60, 359.
Le Cozier, Y., Dagorn, J., Dourmad, J.Y., Johansen, S., Aumaître, A., 1997. Effect of weaning-to-conception interval and lactation length on subsequent litter size in sows. Livestock Production Science 51, 1–11.
Lucia, T., Dial, G.D., Marsh, W.E., 2000. Lifetime reproductive performance in female pigs having distinct reasons for removal. Livestock Production Science 63, 213–222.
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, 15–26.
Nieto, R., García-Casco, J., Lara, L., Palma-Granados, P., Izquierdo, M., Hernandez, F., Dieguez, E., Duarte, J.L., Batorek-Lukač, N., 2019. Ibérico (iberian) pig. In: Čandek-Potokar, M., Nieto Liñán, R.M. (Eds.), European local pig breeds - Diversity and performance. A study of project TREASURE. IntechOpen, London, UK, pp. 115–139.
Noguera, J.L., Ibáñez-Escriche, N., Casellas, J., Rosas, J.P., Varona, L., 2019. Genetic parameters and direct, maternal and heterosis effects on litter size in a diallel cross among three commercial varieties of Iberian pig. Animal 13, 2765–2772.
Patterson, J.L., Beltranena, E., Foxcroft, G.R., 2014. The effect of gilt age at first estrus and breeding on third estrus on sow body weight changes and long-term reproductive performance. Journal of Animal Science 88, 2500–2513.
Pecero Sayago, J.A., 2021. Reposición de nulíparas en cerdo ibérico. Retrieved on 23 June 2022, from https://www.zonaporcino.es/posts/reposicion-nuliparas-iberico.aspx.
Piñeiro, C., Aparicio, M., de Andrés, M.A., Rainho, N., Rodríguez-Estévez, V., 2012. Influence of farrowing number on prolificacy and lactating performance in Iberian pig farms. Proceedings of the 7th International Symposium on the Mediterranean Pig, 14–16 October 2010, Córdoba, Spain, pp. 197–198.
Rabelo, S.S., Faria, B.G., Rocha, L.G.P., Pereira, B.A., 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 Veterinária e Zootecnia 68, 1085–1089.
Robledo, J., Vargas, J.D., González, F., Prieto, L., Andradas, J.A., Aparicio, M., 2007. Animal welfare and production in the Iberian pig. Proceedings of 6th International Symposium on the Mediterranean Pig, 11–13 October 2007, Messina – Capo d́Orlando, Italy, pp. 146–152.
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, 189–192.
Sasaki, Y., Koketsu, Y., 2008. Sows having high lifetime efficiency and high longevity associated with herd productivity in commercial herds. Livestock Science 118, 140–146.
Sasaki, Y., Saito, H., Shimomura, A., Koketsu, Y., 2011. Consecutive reproductive performance after parity 2 and lifetime performance in sows that had reduced pigs born alive from parity 1 to 2 in Japanese commercial herds. Livestock Science 139, 252–257.
Schenkel, A.C., Bernardi, M.L., Bortolozzo, F.P., Wentz, I., 2010. Body reserve mobilization during lactation in first parity sows and its effect on second litter size. Livestock Science 132, 165–172.
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, 969620.
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. Scientific Papers Animal Science and Biotechnologies 47, 281–285.
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, 100033.
Soede, N.M., Hoving, L.L., Leeuwen, J.J.J., van and Kemp, B., 2013. The second litter syndrome in sows; causes, consequences and possibilities of prevention. Proceedings of the 9th International Conference on Pig Reproduction, Satellite Symposium, 09–12 June 2013, Olsztyn, Poland, pp. 28–34.
Thaker, M.Y.C., Bilkei, G., 2005. Lactation weight loss influences subsequent reproductive performance of sows. Animal Reproduction Science 88, 309–318.
Willis, H.J., Zak, L.J., Foxcroft, G.R., 2003. Duration of lactation, endocrine and metabolic state, and fertility of primiparous sows. Journal of Animal Science 81, 2088–2102.