ASSOCIATIONS BETWEEN FIRST PARITY WEAN-TO-SERVICE INTERVAL AND SOW LIFETIME PRODUCTIVITY TRAITS †

[ASOCIACIÓN ENTRE EL INTERVALO PRIMER PARTO-SERVICIO Y CARACTERES DE LA VIDA PRODUCTIVA DE LA CERDA]

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SUMMARY

Background: Sows' lifetime reproductive performance is a key component for farm productive efficiency and profitability. **Objective:** To investigate associations between first parity wean-to-service interval (WSI) and sows' lifetime reproductive performance traits. **Methodology:** Data were collected in a 3,900-sows farrow-to-finish farm in Yucatan, Mexico. Lifetime productivity records included parity number at culling (NCP), lifetime number piglets born alive (LNBA) from parity two until culling, lifetime non-productive days (LNPD) and length of productive life (LPL) for 4,175 sows. Association between WSI and sow lifetime productivity traits were analyzed using general linear models, including year and season at first service as categorical fixed effects and WSI as linear and quadratic predictor. Cut-off values for WSI were estimated using regression trees analysis. **Results:** WSI was negatively associated ($P < 0.05$) with LNBA and NCP, positively ($P < .05$) with LNPD and non-associated with LPL ($P > 0.05$). Cut-off values for WSI varied for each predicted variable: WSI > 5 days would translate into longer 13 more days of LPL, WSI < 7 days would increase LNBA by two extra pigs, WSI ≥ 9 days increase NCP by 0.2 parities and WSI <10 days would mean 24 fewer LNPD. **Conclusions:** Under the conditions of this study, shorter WSI were associated with improved lifetime productivity traits, confirming the importance of traits observed early in life as indicators of performance in subsequent parities.
Key words: swine, piglets born alive, pig production, reproductive performance, sow culling

RESUMEN

Antecedentes: El desempeño reproductivo durantea vida de las cerdas es un componente clave para la eficiencia productiva y la rentabilidad de la granja. **Objetivo:** Investigar las asociaciones entre el intervalo de destete al servicio (WSI) del primer parto y las características de desempeño reproductivo de por vida de las cerdas. **Metodología:** Los datos se recopilaron en una granja de ciclo completo de 3900 cerdas en Yucatán, México. Los registros de productividad de por vida incluyeron el número de parto al desecho (NCP), el número de lechones nacidos vivos (LNBA) desde el segundo parto hasta el sacrificio, los días no productivos de por vida (LNPD) y la duración de la vida productiva (LPL) para 4175 cerdas. La asociación entre el WSI y las características de productividad de por vida de la cerda se analizaron utilizando modelos lineales generales, incluidos el año y la temporada en el primer servicio como efectos fijos categóricos y el WSI como predictor lineal y cuadrático. Los valores de corte para WSI se estimaron mediante el análisis de árboles de regresión. **Resultados:** WSI se asoció negativamente (P < 0.05) con LNBA y NCP,

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positivamente (P < 0.05) con LNPD y no asociado con LPL (P > 0,05). Los valores de corte para WSI variaron para cada variable predicha: WSI > 5 días se traduciría en 13 días más de LPL, WSI < 7 días aumentaría LNBA en dos cerdos adicionales, WSI ≥ 9 días aumentaría NCP en 0.2 partos y WSI < 10 días significaría 24 LNPD menos. **Conclusiones:** Bajo las condiciones de este estudio, WSI más cortos se asociaron con caracteres de productividad de por vida mejores, lo que confirma la importancia de observar caracteres en la vida temprana de las cerdas como indicadores de desempeño en sus partos posteriores.
Palabras clave: cerdos, lechones nacidos vivos, producción porcina, desempeño reproductivo, sacrificio de cerdas.

INTRODUCTION

Sows' lifetime reproductive performance is a key component for farm productive efficiency and profitability. Sows staying longer in the herd produce more litters and lifetime piglets born alive (Koketsu *et al*., 2017) contributing to recoup their initial replacement costs and to improve overall farm financial performance (Gruhot *et al*., 2017b, Stalder *et al*., 2003). There are several metrics to evaluate sow lifetime performance including productive life (i.e. number of days from first farrowing and date of removal), parity at removal, lifetime number of piglets born alive (LNBA) and lifetime number of pigs produced (Calderón-Diaz *et al*., 2015). Factors associated with sow lifetime productivity include: age at puberty and first farrowing (Hoge and Bates 2011, Koketsu *et al*., 2020) body composition, weight at puberty and first service (Kummer *et al*., 2006), number of piglets born alive in early parities (Engblom *et al*., 2015, Gruhot *et al*., 2017a), number of services within a given parity (Koketsu, 2003), and wean-to-service interval (WSI; i.e. the time when the sow's previous litter is weaned to the time of first service for her next litter) in the first parity (Koketsu and Iida, 2020).

Wean-to-first service interval during the first parity could be used as an early in life indicator for sow's subsequent lifetime productivity (Yatabe *et al*., 2019). For instance, in a recent study involving 155 Spanish sow herds reported that sows with a first WSI of 4 or 5 days remained longer in the herd reflected by a higher parity at culling and they produced more LNBA when compared with sows with a first WSI ≥ 6 days. Furthermore, longer WSI is associated with increased number of non-productive days (NPD, i.e., period in which the sow is not pregnant or lactating, but which generates expenses for feeding and handling) and a greater NPD is associated with fewer litters produced per sow per year and lower farrowing rate (Wilson and Dewey, 1993, Yatabe *et al*., 2019). However, information regarding association between first WSI and sow lifetime productivity is scarce in the scientific literature and there is no information regarding cut-off values for WSI that could be used for decision making to maximize sow lifetime productivity. Previous studies have used different subjective classifications for WSI in their analyses, which do not allow for the identification of critical time points where different interventions (e.g., use of hormones for estrus synchronization) could be implemented on-farm for improved reproductive management.

We hypothesize that sows with shorter first WSI have improved lifetime reproductive performance evidence by higher parity at culling (NCP), producing higher LNBA and by having lower number of lifetime non-productive days (LNPD). Hence, the objective of this study was to investigate the association between WSI during the first parity and key sow lifetime productivity indicators.

MATERIALS AND METHODS

Lifetime reproductive data and data management

Data used for this study were collected over a 4-year span (2010 to 2014) from a commercial 3,900 PIC Camborough® sows farrow-to-finish farm located in the state of Yucatan, Mexico. The state of Yucatan is located 19° 30', and 21° 35' north latitude and 90° 24' west longitude. The weather of the region is sub-humid tropical, with rain in summer (1,100 mm), an average annual temperature of 26° C, and relative humidity of 78% (INEGI, 2022). Due to climatic conditions in Yucatan, three climatic seasons are present, namely: dry season (February to May; average monthly temperature = 22.8 to 28.0 °C; rainfall = 26.7 to 105.3 mm, and wind = 19.4 to 19.8 km/h), rainy season (June to September; average monthly temperature = 25.2 to 27.7 °C; rainfall = 128.4 to 169.4 mm, and wind = 18.4 to 18.7 km/h) and windy season (October to January; average monthly temperature = 21.2 to 23.2 °C; rainfall = 30.3 to 60.5 mm, and wind = 21.9 to 23.8 km/h (Nasrat *et al*., 2016).

In this farm, gilts were home reared, housed in groups of 11 females per pen and served on their second estrus, at approximately 210 days of age with a minimum body weight of 140 kg. All females were exposed daily to mature vasectomized boars and they were observed for signs of standing estrus. Estrus was confirmed by applying the back-pressure test. All females were artificially inseminated immediately after estrus confirmation, and again 24 hours after the first service. During gestation, all females were housed in groups of 10 sows, and they were fed according to their parity. Primiparous sows received 2.6 kg of feed/day and multiparous sows received 3.2 kg of feed/day with 3,000 kcal DM/kg, 16% crude protein and 0.8% standard ileal digestible lysine. Sows were transferred to the farrowing accommodation approximately 10 days before their due date where they remain until weaning, which occurs approximately 22 days post-farrowing. During the lactation period, sows were individually housed in farrowing crates and fed *ad libitum*. Cross-fostering was practiced at the farm within 48 hours post-farrowing. Sows are vaccinated against Parvovirus, Erysipelas, Leptospirosis, Mycoplasma hyopneumoniae, Porcine circovirus type 2 and Actinobacillus pleuropneumoniae at weaning and booster at 15 days. In addition, they are vaccinated against Escherichia coli between 12 and 14 weeks of gestation. For all sows, information on farrowing and weaning dates, number of piglets born alive, and date of first post-weaning estrus were recorded using the PigCHAMP® software (PigCHAMP Inc., Ames, Iowa, USA).

For this study, data from sows with complete lifetime performance record were retrospectively acquired from farm records. For each sow data on first parity WSI, year and season at first service and first weaning, NCP, LNBA, LNPD [defined as days a sow was "empty" (i.e., not pregnant or in lactation) from first parity weaning until culling], and length of productive life (LPL; defined as number of days from first farrowing until culling) were obtained. Data editing and categorization was conducted in SAS (16). Data editing was performed to ensure data were within normal physiological ranges and free from recording errors. The complete data set comprised 7,216 records. Sows that did not have complete lifetime performance records (n = 2,756 sows), sows with negative WSI (n = 3 sows) and sows with a WSI > 30 days (n = 285) were not included in the analysis. The final data set included records for 4,175 sows.

Statistical analysis

Residuals of predicted variables (i.e., NCP, LNPD, LNBA and LPL) were tested for normality using the Shapiro-Wilk test and by examining the normal probability plot using the UNIVARIATE procedure of SAS (2012). All predicted variables were normally distributed. General linear model equations were used to investigate the association between lifetime reproductive performance traits and WSI in PROC GLM of SAS (2012). The models included year and season of WSI as fixed effects and WSI as a continuous linear and quadratic predictor. For all analyses, statistical differences were reported when P < .05, while statistical trends were reported when P > 0.05 and P < 0.10. Results for continuous predictors are reported as their regression coefficient ± standard error and for categorical fixed effects as mean ± standard error.

Regression tree analysis was used to estimate cut-off values for WSI associated with improved lifetime reproductive performance. Data were analyzed using the *rpart* package (Therneau *et al*., 2019) of *R* v3.5.2 (2019). The model included NCP, LNPD, LNBA or LPL as the outcome variable and WSI as continuous predictor variable.

RESULTS

Mean WSI was 6.4 ± 5.82 days with 86.6% of sows having a WSI of ≤ 7 days. The percentage of sows by WSI is showed in Figure 1. Increased WSI was associated with fewer LNBA, lower NCP and increased LNPD (P < .05). A quadratic association was observed between WSI and LNBA and between WSI and LNPD (P < 0.005). The minimum value of WSI to optimize LNBA was 16 days while the maximum value of WSI to optimize LNPD was 28 days. The quadratic relationship between WSI and NCP tended to be significant (P = 0.008) with an optimal value of 20 days (Table 1). No associations were observed between WSI and LPL. Sows weaned during the dry season, had more LNBA, were culled at a higher NCP, and had more LNPD compared with sows with WSI occurring during the rainy and windy seasons (P < 0.05).

In total, 1,654 sows had their WSI during the dry season, 1,440 sows during the rainy season and 1,081 during the windy season. There was no difference in LNPD between sows with WSI occurring during the dry and rainy season (P > 0.05); however, these sows had more LNPD when compared with sows with longer WSI during the windy season (P < 0.05).

Results for the regression tree analysis are shown in Figure 2. Results showed that the associated cut-off value for WSI varied according to each of the predicted variables. Cut-off values were identified as follow: WSI > 5 days would translate into longer 13 more days of LPL, WSI < 7 days would increase LNBA by two extra pigs, WSI ≥ 9 days increases NCP by 0.2 parities, and WSI < 10 days would mean 24 fewer LNPD.

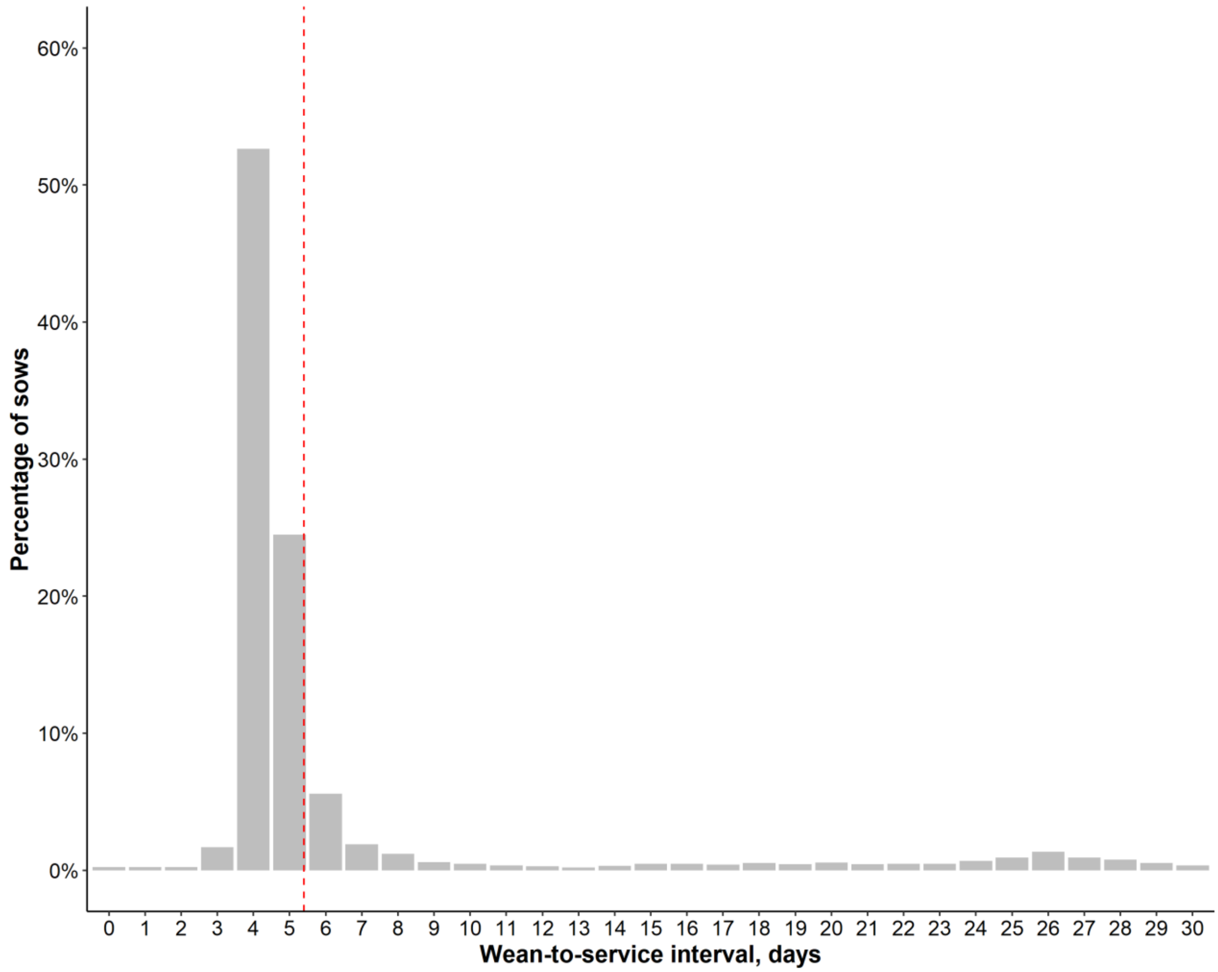

Figure 1. The percentage of sows by weaning-to-service interval.

Table 1. Associations between first parity wean-to-service (WSI), season in which sows were weaned during the first parity, and lifetime reproductive performance traits for 4,175 culled sows in a large commercial farm in the Mexican sub-humid tropical region.

	LNBA[1]		LNPD[2]		NCP[3]		LPL[4]	
Predictor	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**	**LSM**	**SE**
WSI, days (n = 4175)								
Linear	-0.62 ± 0.026*		2.81 ± 0.687*		-0.04 ± 0.018*		-3.45 ± 2.573	
Quadratic	0.02 ± 0.008*		-0.05 ± 0.023*		0.001 ± 0.0001(*)		0.10 ± 0.088	
Season								
Dry (n = 1654)	50.6[a]	0.63	66.2[a]	1.67	4.6[a]	0.04	575.1[a]	6.27
Rainy (n = 1440)	46.2[b]	0.66	63.9[a]	1.77	4.3[b]	0.05	531.9[b]	6.64
Windy (n = 1081)	44.4[c]	0.63	59.6[b]	1.69	4.1[c]	0.05	502.8[c]	6.34

[1] Lifetime number of piglets born alive from parity one until culling; [2] Lifetime non-productive days; [3] Parity number at culling; [4] Length of productive life; * $P \leq 0.05$; (*) $P \leq 0.10$; [a-c] within columns, least squared means with different superscripts are statistically different ($P < 0.05$).

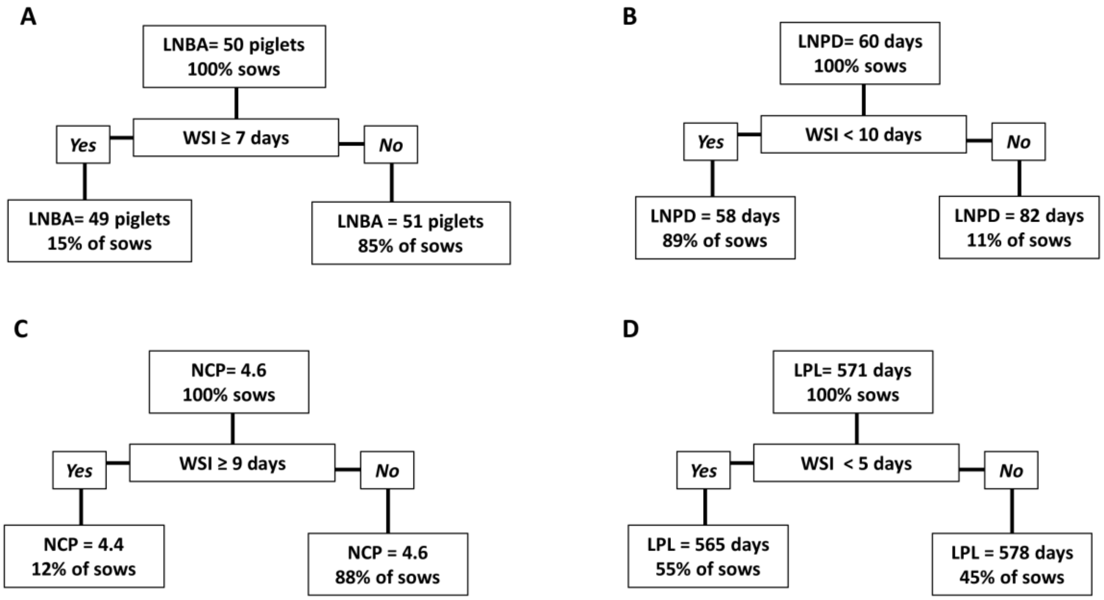

Figure 2. Results for the regression tree analysis. LNBA=Lifetime number of piglets born alive from parity one until culling; LNPD = Lifetime non-productive days; NCP = Parity number at culling; LPL = Length of productive life

DISCUSSION

Under the conditions of this study, sows with shorter WSI would have improved lifetime reproductive performance as indicated by higher LNBA and NCP and lower LNPD. These results agree with those previously reported by other authors in different countries (Koketsu, 1999, Tummaruk *et al*., 2010, Yatabe *et al*., 2019), where similar favorable associations between shorter WSI in first farrowing sows and lifetime reproductive performance traits such as LNBA and lifetime piglets weaned were also observed. Wean-to-service interval is likely associated with different patterns of secretion and concentration of the luteinizing hormone during lactation and the post-weaning periods (Soede *et al*., 2011,Kemp *et al*., 2018) and thus, sows with shorter WSI might return to estrus faster post-weaning due to better activity of the hypothalamic-pituitary-ovary axis (Yatabe *et al*., 2019).

Therefore, it could be possible that first parity sows exhibiting shorter WSI may have higher concentration and secrete more luteinizing hormone allowing for a more efficient recruitment of follicles in the ovaries compared with sows exhibiting longer WSI (Shaw *et al*., 1985, Soede *et al*., 2011, Kemp *et al*., 2018). This would translate to more visible and lasting signs of estrus in weaned sows (Soede *et al*., 2011), facilitating estrus detection and more timely artificial insemination. This would likely contribute to increase conception and farrowing rates, litters produced per sow per year, litter size in subsequent parities and, ultimately to sows producing more piglets during their productive life (Tummaruk *et al*., 2010, Segura-Correa *et al*., 2014, Kemp *et al*., 2018, Koketsu and Iida, 2020). Hence, selection for shorter WSI could be beneficial; however, the low repeatability of WSI suggests that it is a low heritable trait and thus, implementation of good (re)productive management practices would be required to achieve shorter WSI (Yatabe *et al*., 2019, Ek-Mex *et al*., 2015a, Segura-Correa *et al*., 2015).

Season effect on fertility, mediated by temperature and photoperiod, is a worldwide persistent problem (Kraeling and Webel, 2015), particularly temperature in tropical regions. However, in present study, the best sow performance was observed for sows having their first WSI during the dry season, when temperature is the highest in the region. This could be explained because of some management practices carried out during the dry season, such as getting the animals wet, better care of the first parity sows, and probably, the confounding effect of season of first WSI with other management and farm factors commonly expected in retrospective observational studies, like the present one. Season of the year effect on lifetime productive traits under Mexican tropical conditions have been reported previously (Ek-Mex *et al*., 2015b, Mellado *et* *al*., 2018, Ek-Mex *et al*., 2020). Nevertheless, our results emphasize the importance of season of the year on productive traits.

We estimated cut-off values for WSI associated with sow lifetime productivity traits. Previous studies have used subjective classifications to compare the reproductive performance of sows with different WSI. However, an objectively, farm specific estimated cut-off values for WSI could aid producers to identify a “window of opportunity” to implement reproductive management practices to maximize benefits on their farms. Our results from the regression tree analysis suggest that for improved lifetime reproductive performance, sows should return to estrus, and be served, between 5- and 10-days post-weaning, depending on which performance indicator the producer would like to improve. However, as the four lifetime reproductive traits investigated in this study are associated among them (Englblom *et al*., 2015), improvement in one of the traits would results in the improvement of a second trait.

The cut-off values for WSI identified in this study are higher than the mean values of < 5 days, <6 days and 4 to 5 days, previously reported by other authors (Koketsu, 1999, Tantasuparuk *et al*., 2001, Yatabe *et al*., 2019), for LNBA. Koketsu (2005) reported ≤ 7 days for LNPD, and Hoshino and Koketsu (2008) and Yatabe *et al*. (2019) of 4 to 6 days and 4 to 5 days, respectively for NCP, although these values were subjectively defined. The different cut-off values found between studies may be attributable to the different methods, and sample population used for their estimation. We acknowledge that as the cut-off values identified in this study for WSI is specific to this cohort of sows, it would likely differ if records from more animals or more farms were included. Future studies are required to investigate factors influencing the cut-off values that could help to find farm specific management practices to improve sow lifetime reproductive performance.

CONCLUSIONS

Under the conditions of this study: Shorter wean-to-service interval during the first parity was associated with improved lifetime productivity traits as indicated by producing more lifetime piglets born alive produced, sows being culled at higher parity number and sows having less lifetime non-productive days. Implementation of animal nutrition, reproductive management and husbandry practices aiming to reduce wean-to-service interval would benefit pig producers to improve sow reproductive performance. The analysis used in this study estimate the cut-off values for wean-to-service interval, which illustrates an easy-to-understand objective method that could be used by pig producers to decide when to implement such strategies.

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Conflict of interest. The authors declare no to have any conflict of interest.

Compliance with ethical standards. Because not live animals were used in this study there is no ethical standards to declare.

Data availability. Data are available with José C. Segura Correa, jose.segura@correo.uady.mx upon request.

Authors contribution statement (CRediT). **J.C. Segura-Correa -** Data curation, formal analysis and writing original draft **E. Ek-Mex -** Data curation, formal analysis and writing original draft, **J. Calderón-Diaz -** Data curation, formal analysis and writing original draft., **Germani Muñoz-Osorio -** Writing - review & editing. **R Santos-Ricalde -** Writing - review & editing. **L.Sarmiento-Franco**, Writing - review & editing.

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