Associations Between First Parity Wean-to-Service Interval and Sow Lifetime Productivity Traits

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Abstract

This study aimed to 1) investigate associations between first parity wean-to-service interval (WSI) and sows' lifetime reproductive traits and 2) identify cut-off values for WSI associated with lifetime traits. Data collected in 3,900 sows of farrow-to-finish commercial farm in Yucatan, Mexico. Lifetime productivity records including parity number at culling (NPC), lifetime number piglets born alive (LNBA) from parity two until culling, lifetime non-productive days (LNPD) and length of productive life (LPL) for sows were used. Association between WSI and sow productive traits were evaluated using general linear models, including year and season as categorical fixed effects and WSI as a continuous linear and quadratic predictors. Cut-off values for WSI were estimated using regression tree analysis. WSI was associated ($P < 0.05$) with LNBA (linear = -0.62 ± 0.025; quadratic 0.02 ± 0.008) and NPC (linear = -0.04 ± 0.018). Similarly, an association ($P < 0.05$) was observed between WSI and LNPD (linear = 2.81 ± 0.687; quadratic -0.05 ± 0.023). Cut-off values for WSI varied according to each of the predicted variables: 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 NPC by 0.2 parities, and WSI < 10 days would mean 24 fewer LNPD. Shorter WSI during the first parity was associated with improved lifetime productivity traits. The estimated cut-off values for WSI could be used by producers, to decide when to implement strategies to improve management.

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 Díaz et al. 2015). Factors associated with sow lifetime productivity traits 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 from 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 (Koketsu and Iida 2020). For instance, in a recent study involving 155 Spanish sow herds, Yatabe et al. (2019) 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 also 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 a decreased number
of 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 (NPC), producing higher LNBA and by having lower number of lifetime non-productive days (LNPD). Hence, the objective of this study were to 1) investigate the association between WSI during the first parity and key sow lifetime productivity indicators and 2) identify cut-off values for WSI associated with sow lifetime productivity traits.

**Materials And Methods**

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% (Instituto Nacional de Estadística y Geografía, 2010). Due to climatic conditions in the Yucatan Peninsula, 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, which 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. 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, NPC, 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 v9.4 (SAS Inst., Cary, NC). 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 (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 \( P < 0.05 \), 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. Results for categorical fixed effects are reported as means ± standard error of the mean.

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 (R Core Team 2019). The model included NCP, LNPD, LNBA or LPL as the outcome variable and WSI as continuous predictor variable.

**Results**

**Associations between lifetime reproductive performance traits and WSI**

Mean WSI was 6.4 ± 5.82 days with 86.6% of sows having a WSI of ≤ 7 days. The proportion of sows by WSI is shown in Figure 1. Increased WSI was associated with fewer LNBA, lower NCP and increased LNPD (\( P < 0.05 \)). 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 dry season (\( P < 0.05 \)).
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 ($P < 0.05$).

**Cut-off values for WSI**

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

**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 are in agreement with those previous reported by Koketsu (1999) Tantasuparuk et al. (2001) and 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 (Kemp et al. 2018; Soede et al. 2011) 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 (Kemp et al. 2018; Shaw and Foxcroft 1985; Soede et al. 2011). 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 (Kemp et al. 2018; Koketsu and Iida 2020; Segura Correa et al. 2014; Tummaruk et al. 2010). 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 (Ek-Mex et al. 2015; Segura-Correa et al. 2015; Yatabe et al. 2019).

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 the 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 suggest that other factors, not identified here, may affect sow performance. Season effect on lifetime productive traits under Mexican tropical conditions have been reported previously (Ek-Mex et al. 2020; Ek-Mex et al. 2015; Mellado et al. 2018).
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 (Engblom 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 those previously reported by Tantasuparuk et al. (2001) Yatabe et al. (2019) and Koketsu. (1999) of < 5 days, 4 to 5 days and < 6 days, respectively for higher LNBA, by Koketsu (2005) of ≤ 7 days for LNPD and by 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.

In conclusion, under the conditions of this study, shorter WSI during the first parity was associated with improved lifetime productivity traits as indicated by more lifetime piglets born alive produced, sows being culled at higher parity number and sows having less lifetime non-productive days. This confirms previous studies about the importance of traits observed early in life as indicators of performance in subsequent parities. 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 illustrates an easy to understand objective method that could be used by pig producers to decide when to implement such strategies.

Declarations

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i) Funding: Not applicable.

ii) Conflict of interest/Competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
iii) Ethics approval. Animal ethics committee approval was not obtained for this study because the data used here were retrospectively obtained from a private company's existing database.

iv) Consent to participate. All authors of the manuscript have consented to participate.

v) Consent for publication. All authors have approved to publish the manuscript.

vi) Availability of data and material. Data will be provided under reasonable request.

vii) Code availability. No applicable.

viii) Authors’ contributions. José Candelario Segura-Correa: Study coordinator, drafting first version of the manuscript, supervision. Jesús Enrique Ek-Mex: Study conceptualization, methodology, data collection, reviewed and revised the manuscript. Germán Muñoz-Osorio, Ronald Santos-Ricalde and Luis Sarmiento-Franco: Contributed to outlining the research focus of the article, reviewed and revised the manuscript. Julia Adriana Calderón Díaz: Data curation, statistical analysis, reviewed and revised the manuscript. All authors read and approved the final manuscript.

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

| Predictor                  | LNBA     | LNPD    | NCP     | LPL      |
|----------------------------|----------|---------|---------|----------|
|                            | LSM      | SE      | LSM     | SE       | LSM      | SE       |
| WSI, days (n = 4175)       |          |         |         |          |          |         |
| Linear                     | -0.62 ± 0.0258* | 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(c) | 0.10 ± 0.088 |
| Season                     |          |         |         |          |          |         |
| Dry (n = 1654)             | 50.6a    | 0.63    | 66.2a   | 1.67     | 4.6a     | 0.04     | 575.1a   | 6.27     |
| Rainy (n = 1440)           | 46.2b    | 0.66    | 63.9a   | 1.77     | 4.3b     | 0.05     | 531.9b   | 6.64     |
| Windy (n = 1081)           | 44.4c    | 0.63    | 59.6b   | 1.69     | 4.1c     | 0.05     | 502.8c   | 6.34     |

LNBA= Lifetime number of piglets born alive from parity two until culling; LNPD=Lifetime non-productive days; NCP=Parity number at culling; LPL=Length of productive life; * P ≤ 0.05; (c) P ≤ 0.10; a-c within columns, least squared means with different superscripts are statistically different (P < 0.05).

Figures
Figure 1

Proportion of sows by wean-to-service interval during the first parity. The figure includes information for 4,175 first parity sows originating from a single farm in the state of Yucatan, Mexico. The red dashed line indicates the mean for wean-to-service interval.
Figure 2

Regression tree analysis cut-off values for wean-to-service interval (WSI) at parity one associated with lifetime reproductive performance. The model included A) lifetime number of piglets born alive (LNBA), b) lifetime non-productive days (LNPD), C) parity number at culling (NCP) and D) length of productive life (LPL) as the outcome variables and WSI as predictor variable.