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Breed and environmental factors of sows and their repeatabilities in central Mexico¤

Factores raciales y ambientales que afectan características reproductivas de las cerdas y sus repetibilidades en México central

Fatores raciais e ambientais que afetam características reprodutivas das porcas e suas repetibilidades em México central

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Summary

Background: reproductive traits influence lifetime productivity of sows. **Objective:** to determine the effects of year and season of farrowing, parity number, and breed, on litter size at birth, weaning to service interval (WSI), farrowing to service interval (FSI), and to estimate their repeatabilities. **Methods:** data from years 1998 to 2008 from a farm in La Piedad, Michoacan, Mexico, were used. Sow breeds were Camborough 22 (PIC), Yorkshire (Y), F_1 Landrace x Yorkshire (F_1 LY), and ¼ Landrace x ¾ Yorkshire (LY3/4). The studied traits were total pigs born at birth (TPB, n = 45,798), number of pigs born alive (PBA, n = 45,798), WSI (n = 41,156), and FSI (n = 41,156). The statistical model for TPB and PBA included the effects of farrowing year, farrowing season, parity number, breed, and year/season interaction. The model for WSI and FSI included the above factors plus the linear and quadratic effects of lactation length. **Results:** the overall means for TPB, PBA, WSI, and FSI were 9.31 pigs, 8.60 pigs, 7.87 days, and 29.9 days, respectively. All effects included in the statistical models were significant ($p<0.05$), except season for TPB and PBA. TPB and PBA increased up to parity 4 and decreased thereafter. The LY3/4 and PIC breed groups had the highest litter size means. The shortest WSI and FSI corresponded to the fall season and the largest to the summer season. WSI and FSI decreased with parity. The Y breed had the shortest and the F_1 LY sows had the highest WSI and FSI. The repeatability estimates for TPB, PBA, WSI, and FSI were 0.13, 0.12, 0.14, and 0.14, respectively. **Conclusions:** year, parity, breed, and lactation length affected litter size, WSI, and FSI. Repeatabilities were low, suggesting that environmental factors are more important than genetic factors for improving the reproductive traits.

Keywords: *farrowing to service interval, litter size, pigs born alive, total pigs born, weaning to service interval.*

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Resumen

Antecedentes: las características reproductivas afectan el tiempo de vida productivo de la cerda. **Objetivo:** determinar el efecto del año de parto, época de parto, número de parto y grupo racial sobre características de la camada al nacimiento, intervalo destete servicio (WSI), intervalo parto servicio (FSI), y estimar sus repetibilidades. **Métodos:** se utilizaron los datos de 1998 a 2008 de una granja en La Piedad, Michoacán, México. Las cerdas pertenecían a los grupos raciales Camborough línea 22 (PIC), Yorkshire (Y), F_1 Landrace x Yorkshire (F_1LY), y ¼ Landrace ¾ x Yorkshire (LY3/4). Las características estudiadas fueron el total de lechones nacidos (TPB, n = 45.798), número de lechones nacidos vivos (PBA, n = 45.798), intervalo destete a servicio (WSI, n = 41.156) e intervalo parto a servicio (FSI, n = 41.156). El modelo estadístico para TPB y PBA incluyó los efectos de año de parto, época de parto, número de parto, grupo racial, y la interacción de año por época. El modelo para WSI y FSI incluyó además los efectos lineal y cuadrático de duración de la lactación. **Resultados:** las medias para TPB, PBA, WSI y FSI fueron 9,31 lechones, 8,60 lechones, 7,87 días y 29,9 días, respectivamente. Todos los efectos incluidos en los modelos fueron significativos ($p<0,05$), excepto época para TPB y PBA. TPB y PBA aumentaron hasta el cuarto parto para disminuir posteriormente. Los grupos raciales LY3/4 y PIC tuvieron las mayores medias para tamaño de camada. Los WSI y FSI más cortos correspondieron a la época de otoño. WSI y FSI disminuyeron con el número de parto. La raza Y tuvo los WSI y FSI más cortos y el grupo F_1 LY los intervalos más largos. Las repetibilidades para TPB, PBA, WSI y FSI fueron: 0,13, 0,12, 0,14 y 0,14, respectivamente. **Conclusiones:** el año, número de parto, grupo racial y duración de la lactación afectaron los tamaños de camada, WSI y FSI. Las repetibilidades fueron bajas, lo que sugiere que los factores ambientales son más importantes que los factores genéticos cuando se quiere mejorar las características reproductivas.

Palabras claves*:* *intervalo destete servicio, intervalo parto servicio, lechones nacidos vivos, tamaño de camada, total de lechones nacidos.*

Resumo

Antecedentes: as características reprodutivas afetam a produtividade de por vida da porca. **Objetivo:** determinar o efeito de ano de parto, época de parto, número de parto e grupo racial sobre características da ninhada ao nascimento, intervalo desmama serviço (WSI), intervalo parto serviço (FSI) e estimar suas repetibilidades. **Métodos:** utilizaram-se os dados de 1998 a 2008 de uma granja em La Piedad, Michoacán, México. As porcas pertenciam aos grupos raciais Camborough línea 22 (PIC), Yorkshire (Y), F_1 Landrace x Yorkshire (F_1 LY) y ¼ Landrace ¾ x Yorkshire (LY3/4). As características estudadas foram o total de leitões nascidos (TPB, n = 45.798), número de leitões nascidos vivos (PBA, n = 45.798), WSI (n = 41.156) e FSI (n = 41.156). O modelo estadístico para TPB e PBA inclui os efeitos de ano de parto, época de parto, número de parto, grupo racial e a interação de ano por época. O modelo para WSI e FSI inclui ademais os efeitos lineais e quadráticos do largo de lactação. **Resultados:** as medias para TPB, PBA, WSI e FSI foram 9,31 leitões, 8,60 leitões, 7,87 dias e 29,9 dias, respectivamente. Todos os efeitos incluídos em os modelos foram significativos ($p<0,05$), exceto época para TPB e PBA. TPB e PBA aumentaram hasta o quarto parto para diminuir posteriormente. Os grupos raciais LY3/4 e PIC mostraram as maiores meias para tamanho de ninhada. Os WSI e FSI mais curtos corresponderam má a época de outono. WSI e FSI diminuíam com o número de parto. A raça Y tubo os WSI e FSI mais curtos e os grupo F_1LY os intervalos mais largos. As repetibilidades para TPB, PBA, WSI e FSI fórum: 0,13, 0,12, 0,14 e 0,14, respetivamente. **Conclusões:** o ano, número de parto, grupo racial e largo de lactação afetaram o tamanho de ninhada WSI e FSI. As repetibilidades foram baixas, o que sugere que os fatores ambientais são mais importantes que os fatores genéticos em a melhora das características reprodutivas.

Palavras chave: *intervalo desmama serviço, intervalo parto serviço, leitões nascidos vivos, tamanho da ninhada, total de leitões nascidos.*

Introduction

Pig production is an important livestock activity in Mexico, which was ranked eighth pork producer at the world level in 2010 (USDA and European Commission, 2012). Reproductive traits and factors affecting them vary with genetic improvement and management changes.

The number of pigs born alive (PBA), number of pigs weaned, pregnancy rate, lactation length, mortality, and farrowing to service interval (FSI) can influence lifetime productivity of sows. Litter size is one of the main components of sow productivity and the target of genetic improvement in recent years; it is also an important factor in pre-weaning mortality.

Litter size is influenced by genetic and environmental factors such as breed, gilt management, lactation length, parity number, disease, stress, and boar fertility (Lawlor and Lynch, 2007). Weaning to service interval (WSI) is an important component of non-productive days of the sow. In turn, non-productive days is a very important economic trait in commercial pig production because sows with long non-productive days increase maintenance costs and decrease profitability (Chansomboon *et al*., 2009). Studies on litter traits at birth and weaning have been reported for commercial swine farms in different countries (Aherne, 2002; Lawlor and Lynch, 2007; Radojkovic *et al.,* 2007). In Mexico, one study was carried out in the Northern region (Segura and Segura, 1991) and another in the Southern region (Gómez-Medina, 1999). A paper with data collected from central Mexico was also published (Ortega *et al.,* 2000); however, it did not evaluate WSI and FSI.

Litter and reproductive traits of sows are usually associated with parity number, estrus length, time of ovulation, and previous litter size (Cavalcante-Neto *et al*., 2008; Karveliene *et al*., 2008). Reproductive traits may be also influenced by other factors such as year, season, temperature, nutrition, stress, and age of the sow (Antunes, 2007; Lundgren *et al*., 2010).

Litter size, WSI, and FSI are traits that occur more than once in the lifetime of the sow; therefore, the intra-class correlation coefficient (repeatability) for those traits can be estimated. Repeatability estimates the upper value of heritability and is calculated when estimating heritability is impossible. Few repeatability estimates have been reported for litter size and farrowing interval in Mexico, and none have been given for FSI or WSI. It is known that genetic parameters should be estimated for each population in order to obtain more reliable breeding values and predicted ability values of sows.

Thus, the objectives of this study were to determine the effects of breed and environmental factors on litter size at birth, WSI, FSI, and to estimate repeatabilities of those traits for a representative farm in central Mexico.

Materials and methods

Data from 1998 to 2008 recorded in a full-cycle commercial farm with approximately 2,400 sows, representative of this production system in La Piedad region, Michoacan, Mexico, were used. The farm was located between 19°20’N and 122°07’W, at 1,675 meters above sea level (INEGI, 2010). The climate of the region is temperate, with 19.1 °C average temperature, warm summers, and 772 mm rainfall, mainly from June to September. Sow breeds were Camborough 22 line (PIC), Yorkshire (Y), F_1 Landrace x Yorkshire (F_1 LY), and ¼ Landrace x ¾ Yorkshire (LY3/4). Sows were vaccinated against common diseases in the region. Sows were fed commercial diets, housed in crates and checked for estrus twice a day using a mature boar. Sows were inseminated every 12 hours after estrous detection, completing three inseminations. Cross-fostering was practiced on the farm.

The studied traits were total pigs born at birth (TPB, n = 45,798), number of pigs born alive (PBA, n = 45,798), weaning to service interval (WSI, n = 41,156), and farrowing to service interval (FSI, n = 41,156) from 6,809 sows. TPB included those pigs born dead or dead within the first 24 hours from birth. To determine the effect of farrowing season on reproductive traits, the months in which parities occurred were divided into four groups: spring (March to May), summer (June to August), fall (September to November), and winter (December to February). Preliminary analysis did not show significant effects (p>0.05) of year per breeding group and season per breeding group interactions. Therefore, they were not included in the final model.

The statistical model that described litter size traits was:

$$y_{ijklm} = \mu + YF_i + SF_j + PA_k + BG_l + YF_i{*}SF_j + sow(GE)_{ijklm} + e_{ijklm}$$

Where:

y_{ijklm}: observed value of the TPB or PBA.

μ: overall mean associated with each observation.

YF_i: fixed effect of the i-th year of farrowing (1998 to 2008).

SF_j: fixed effect of the j-th season of farrowing (spring, summer, fall, and winter).

PA_k: k-th parity number.

BG_l: fixed effect of the l-th breed group of the sow (PIC, Y, F_1 LY, and LY3/4).

$YF_i{*}SF_j$: interaction of YF by SF.

Sow $(BG)_{ijkl}$: random effect of sow nested within BG.

e_{ijkl}: random error associated with each observation, with $\mu = 0$ and variance $= \sigma^2_e$.

The statistical analysis was performed using the MIXED procedure with REPEATED option of SAS (2008) program (Statistical Analysis System Institute, Cary, NC, USA). The model for WSI and FSI included the factors in the litter size model plus the linear and quadratic effects of lactation length (mean = 22 days).

Repeatability estimates and standard errors were calculated using the between and within sow components of variance produce by the MIXED procedure, according to the formulae provided by Becker (1992). The correlation of WSI with FSI was calculated using the CORR procedure (SAS, 2008).

Results

Overall means and standard deviations for TPB, PBA, WSI, and FSI were 9.31 ± 2.75 pigs, 8.60 ± 2.78 pigs, 7.87 ± 7.80 days, and 29.9 ± 7.80 days, respectively. Lactation length had a mean and standard deviation of 22.0 ± 2.96 days. 86.7% of the sows had been serviced by day 14 after weaning, and 90.7% by day 18.

All main effects and farrowing year by farrowing season interaction were significant ($p<0.05$) for all traits, except season for TPB and PBA. The least square means of the main effects included in the statistical models are shown in Table 1. The shortest intervals corresponded to sows farrowing during fall. However, this was not the best season, as suggested by the year by season interaction. Litter size (TPB and PBA) increased up to parity 4 and decreased thereafter. The LY3/4 and PIC breed groups had the highest litter size.

The WSI and FSI decreased with parity. The Y, PIC, and LY3/4 groups had shorter and similar ($p<0.05$) WSI and FSI means than the F_1 LY breed group.

Lactation length had negative linear (-1.79 ± 0.04) and positive quadratic (0.036 ± 0.001) effects on WSI. Figure 1 shows the relationship between predicted WSI and lactation length. The regression equation for FSI was $27.6 - 0.974X + 0.036X^2$. The lactation length that produced the lowest predicted WSI and FSI was 25 days. The simple correlation of WSI and FSI was 0.877.

The repeatability estimates and standard errors for TPB, PBA, WSI, and FSI were 0.13 ± 0.004, 0.12 ± 0.004, 0.14 ± 0.005, and 0.14 ± 0.005, respectively. Repeatabilities were significantly different from zero ($p<0.05$).

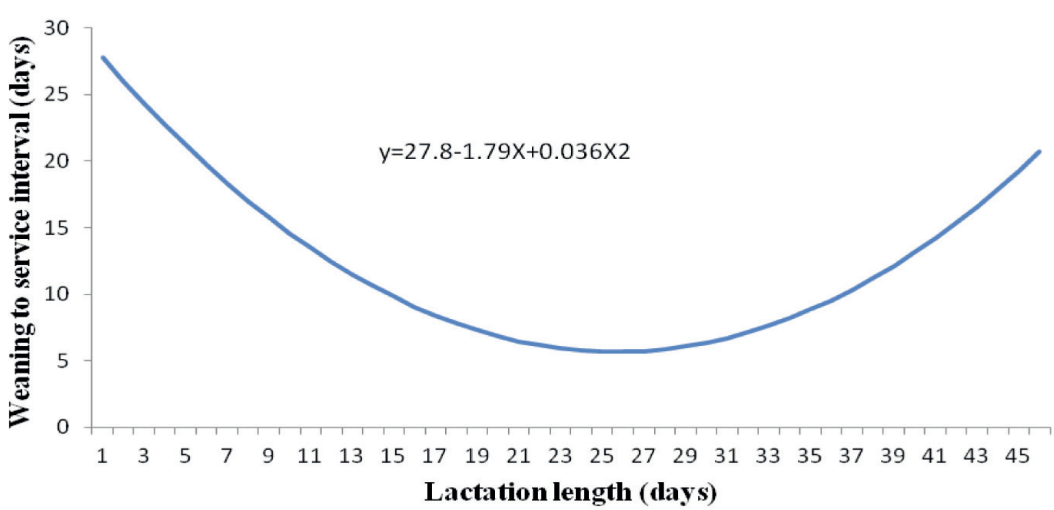

Figure 1. Effect of lactation length on weaning to service interval.

Table 1. Least square means by main factors for reproductive traits of sows from a farm (capacity = 2400 sows) in Michoacan, Mexico.

Factor	N*	TPB	PBA	N**	WSI	FSI
Year of farrowing						
1998	3269	9.26±0.058^{d}	9.03±0.058^{f}	3084	6.47±0.249^{a}	28.2±0.25^{a}
1999	4379	9.35±0.050^{e}	8.81±0.051^{e}	3762	8.07±0.164^{e}	29.9±0.16^{d}
2000	4774	9.20±0.047^{c}	8.57±0.048^{d}	4314	6.88±0.152^{ab}	28.7±0.15^{ab}
2001	4598	9.47±0.046^{f}	8.72±0.046^{e}	3913	7.99±0.152^{e}	29.8±0.15^{d}
2002	4159	10.16±0.047^{h}	9.24±0.047^{g}	3890	7.32±0.145^{cd}	29.1±0.14^{c}
2003	4070	9.47±0.046^{f}	8.66±0.047^{de}	3818	8.62±0.143^{f}	30.4±0.14^{d}
2004	3783	9.55±0.047^{f}	8.44±0.048^{c}	3365	7.66±0.153^{de}	29.4±0.15^{cd}
2005	3417	8.90±0.049^{b}	8.19±0.050^{b}	3018	7.34±0.160^{cd}	29.1±0.16^{c}
2006	4395	8.93±0.047^{b}	8.19±0.047^{b}	4008	7.08±0.150^{bc}	28.9±0.15^{bc}
2007	5623	8.50±0.044^{a}	7.74±0.045^{a}	5021	7.09±0.142^{bc}	28.9±0.14^{bc}
2008	3331	8.48±0.058^{a}	7.65±0.058^{a}	2963	8.26±0.182^{fe}	34.4±0.18^{e}
Season of farrowing						
Spring	11706	9.21±0.031^{a}	8.49±0.031^{a}	10480	7.80±0.101^{c}	29.6±0.10^{c}
Summer	11887	9.22±0.030^{a}	8.44±0.031^{a}	10628	8.73±0.099^{d}	30.5±0.10^{d}
Fall	10691	9.16±0.032^{a}	8.45±0.033^{a}	9608	6.51±0.104^{a}	28.3±0.10^{a}
Winter	11514	9.24±0.031^{a}	8.52±0.031^{a}	10440	7.06±0.100^{b}	28.8±0.10^{b}
Parity number						
1	7667	8.63±0.034^{b}	7.87±0.035^{b}	7621	11.61±0.102^{e}	33.4±0.10^{e}
2	7952	9.26±0.034^{d}	8.67±0.034^{d}	7489	8.05±0.102^{d}	29.8±0.10^{d}
3	7177	9.68±0.035^{ef}	9.05±0.035^{f}	6742	7.24±0.106^{c}	29.0±0.11^{c}
4	6199	9.75±0.037^{g}	9.05±0.037^{f}	5805	7.22±0.113^{c}	29.0±0.11^{c}
5	5113	9.62±0.040^{f}	8.88±0.041^{e}	4699	6.79±0.123^{b}	28.5±0.12^{b}
6	4205	9.46±0.044^{e}	8.70±0.045^{d}	3724	6.69±0.137^{b}	28.6±0.14^{b}
7	3313	9.18±0.049^{d}	8.38±0.050^{c}	2560	6.62±0.163^{ab}	28.4±0.16^{ab}
8	2206	8.90±0.059^{c}	8.10±0.060^{b}	1708	6.38±0.197^{a}	28.2±0.20^{a}
9	1966	8.39±0.065^{a}	7.59±0.066^{a}	808	6.13±0.297^{a}	27.9±0.30^{a}
Breed group						
PIC	20847	9.24±0.027^{b}	8.47±0.027^{bc}	18642	7.42±0.088^{a}	29.2±0.09^{a}
Y	13872	9.12±0.033^{a}	8.40±0.033^{ab}	12620	7.28±0.105^{a}	29.1±0.10^{a}
F_1L	3651	9.16±0.064^{ab}	8.44±0.064^{ab}	3280	7.99±0.203^{b}	29.8±0.20^{b}
LY3/4	7428	9.31±0.042^{b}	8.60±0.041^{c}	6614	7.42±0.131^{a}	29.2±0.13^{a}

*Number of litters; **number of intervals; TPB = Total pigs born (dead and alive); PBA = number of pigs born alive per litter; WSI = Weaning to service interval; FSI = Farrowing to service interval. $^{a,b,c,d\ e,f,g}$ means with different superscript differ significantly (p>0.05).

Discussion

The means for TPB and PBA (9.31 and 8.60 pigs, respectively) obtained in this study are lower than those reported by Lawlor and Lynch (2007) for European countries (from 11.2 to 12.7 for PBA), and lower than those reported by Radojkovic *et al.* (2007) for the first three litters in Serbia (9.78 TPB and 9.19 PBA). Gómez-Medina *et al.* (1999) reported 11.0 and 10.2 piglets per litter in Yucatan, Mexico. Differences may be due to geographical location, management, breed, population structure, and the presence of diseases. Therefore, it is important to identify the specific factors affecting traits of economic interest for each farm or production system. Although results from one farm may not be extrapolated to other production systems, they can be used as a benchmark for this or other farms.

The year by season interaction found in this study indicates that reproductive performance varied between seasons but depending on the year. Interaction results of year by season are not shown, because they have no practical value, as they are not repeatable. However, interaction was included in the statistical model to remove the non-additive effects of the main factors involved. Management decisions to reduce the effect of season on reproductive traits are difficult to make when interactions occur. Although main effects should not be discussed separately when interactions exist, year of farrowing is complex to explain in retrospective studies like this, because it involves many confounded factors. Effects of year of farrowing on litter size have been reported in other countries (Kim *et al*., 1998; Lawlor and Lynch, 2007) and Northeastern (Segura and Segura, 1991) and Southeastern Mexico (Gómez-Medina *et al*., 1999).

Season had no effect on litter traits, which agrees with results of Radojkovic *et al*. (2007) and Pandey *et al*. (2010). However, other authors have reported seasonal effects (Estany and Sorensen, 1995; Gómez-Medina *et al.,* 1999). The effect of season is associated mainly to climatic effects and the presence of diseases in commercial pig farms.

Litter size increased from the first to the fourth parity and decreased in further parities coinciding with previous reports (Hughes, 1998). Therefore, it is important to keep a low proportion of young (1 and 2 parities) and old (>8 parities) sows in the herd in order to improve the herd performance. To achieve this goal, culling rates must be optimized and it is especially important to avoid situations where excessive numbers of 4 to 6 parity-sows are culled.

The high litter size obtained was due to LY3/4 and PIC sows as compared to Y and F_1 LY sows. As a result of heterosis, crossbred sows are expected to perform better than pure breed sows. The better performance of LY3/4 compared with F_1 LY sows may be due to the fact that the former cross considers both maternal and direct effects of the sows, whereas the latter considers only individual genetic effects. Aherne (2002) reported that litter size of crossbred sows is, on average, 0.25 to 0.5 pigs greater than that of purebred sows. According to Johnson *et al.* (1999), genetic improvement programs should emphasize selection for PBA and weight of live born pigs instead of TPB because of undesirable genetic relationships between ovulation rate and number of fetuses with numbers of stillborn and mummified pigs, and because birth weight decreases as litter size increases. Lakhani and Jogi (2001) and Pandey *et al*. (2010) reported breed group differences in litter size at birth in India.

Repeatability estimates for TPB and PBA were lower than those (0.16) obtained by Siewerdt *et al.* (1995) and Su *et al*. (2007) for Landrace (0.17) and Yorkshire (0.15) breeds. Kyung-Soo *et al*. (2010) reported 0.17 and 0.20 repeatability estimates for Landrace and Yorkshire in Korea. However, they were similar to 0.12, the value calculated in a Croatian study (Lukovic *et al*., 2007), and higher than 0.09, as reported by Nguyen *et al*. (2006) in Australia.

From a statistical point of view, WSI and FSI are the same variable as indicated by the high Pearson correlation coefficient obtained between both variables (r = 0.88). This may be explained by the low variation in lactation length. As a result, the same factors influencing WSI affected FSI.

WSI (7.87 days) was shorter than the weaning to breeding interval (10.2 days) reported by Schwartz *et al*. (2009) and the weaning to first service interval (9.34 days) reported by Karveliene *et al.* (2008). It is, however, longer than the weaning to estrous intervals (5.70 and 6.47 days) reported by Suwanasopee *et al*.

(2005a) and Chansomboon *et al*. (2009). Lower means were reported by Carregaro *et al*. (2006) and Poleze *et al*. (2006). Cavalcante-Neto *et al*. (2008) explain that this may be the result of human error in the detection of estrus, since sow could present reflection of tolerance to the boar, but does not exhibit this to humans.

No reports on FSI were found in the literature, perhaps because WSI is more often used as an estimator of non-productive days, which is a better variable to determine profitability. The FSI obtained (29.9 days) is shorter than the 31.4 days farrowing to conception interval reported by Koketsu and Dial (1997); this was probably due to the fact that some sows require more than one insemination to get pregnant.

Year of farrowing is a common source of variation for WSI and similar traits (FSI, weaning to estrus interval). As mentioned before, year is a difficult to explain factor because it is the result of many sources of variation such as farmer decisions, herd management and climatic changes. Significance values of the year by season interaction for reproductive traits are not shown because year effects are not repeatable. However, they could be of interest when studying yearly productivity trends. WSI means by year of farrowing ranged from 6.10 days for year 1998 to 8.47 for 2008. Year of farrowing influence on WSI or weaning to estrous interval were reported by Suwanasopee *et al.* (2005a) in Thailand and Leite *et al*. (2011) in Brazil.

The lowest weaning to estrous interval was obtained in the fall season (6.44 days) while sows had longer weaning to estrous interval (8.59 days) during summer. This disagrees with Cavalcante-Neto *et al.* (2008) in Brazil and Chansomboon *et al.* (2009) in Thailand, who did not find significant influence of farrowing season. The difference obtained in the weaning to estrous interval among farrowing seasons may be related to voluntary feed intake, especially during lactation, which is influenced by environmental temperature. Bortolozzo and Wents (2004) found satisfactory feed consumption of sows in winter and lower consumption in summer. The above explanation also applies to FSI. WSI and FSI decreased with parity number, which agrees with findings of Suwanasopee *et al.* (2005a) for weaning to estrous interval. This may be due to primiparous sows, which have higher nutrient requirements for growth, since they have not yet reached adult size and weight and have limited body reserves of protein and fat. These higher demands for growth in addition to nutritional demands for milk synthesis for their first litter may strain their ability to return to estrus as quickly as multiparous sows do after weaning (Poleze *et al*., 2006; Chansomboon *et al*., 2009). First-parity sows do not have a satisfactory feed intake during lactation, causing weight loss (Karveliene *et al*., 2008), delaying estrous, and, thus, increasing weaning to estrous interval.

The effect of breed group on WSI and FSI intervals agrees with findings of Suwanasopee *et al.* (2005a) and Chansomboon *et al*. (2009) for weaning to estrous interval, however, disagrees with the results of Poleze *et al.* (2006), who reported that genotype does not directly interfere in weaning to estrous interval, but indirectly interferes through genetic variation in the susceptibility to the factors that may prolong this interval. However, different results could be obtained for genotypes or breed groups because breed varies in ovulation rate, uterus capacity, milk production, and maternal responsiveness (Rydhmer *et al*., 1995), and environmental factors, including climate, season, and herd management (Dewey *et al*., 1995).

The estimated regression coefficients produced concave lines when predicted WSI or FSI were plotted against lactation length. The lowest WSI and FSI values occurred at 25 days. Similar results were reported by Mabry *et al.* (1996) in the United States in 13 commercial herds using 178,519 litters from crossbred and purebred sows. However, in a study in Thailand, the smallest WSI values occurred between 26 and 32 days of lactation (Chansomboon *et al*., 2009). A reduction in weaning to estrous interval, caused by an increase in lactation length, was described by Koketsu and Dial (1997), Tummaruk *et al*. (2000) and Leite *et al*. (2011). However, Tantasuparuk *et al*. (2000) and Chansomboon *et al*. (2010) reported no influence of lactation length. The differences found in the literature may be attributed to genetics and factors directly related to lactation, such as feed intake, which affects the body weight lost by the sow during lactation (Mabry *et al*., 1996; Antunes, 2007; Cavalcante-Neto *et al*., 2008). Thus, the relationship between weaning to estrous interval, WSI or FSI, and lactation length should always be verified in the herd under study because it varies from herd to herd and may be subject to control in the management system.

Repeatability estimates for WSI and FSI (0.14 and 0.14) are higher than the values found by Suwanasopee *et al.* (2005b) and Chansomboon *et al*. (2009; 0.08 and 0.10, respectively). These low repeatability estimates emphasize the importance of obtaining several records per sow for weaning to service interval and litter traits in order to improve prediction accuracy of future records as well as to increase the prediction accuracy of sow, boar and progeny in pig populations (Chansomboon *et al*., 2009). Estimates for WSI obtained by Hanenberg *et al*. (2001) ranged from 0.08 to 0.19. Repeatability estimates for WSI and FSI are lower than those reported by Leite *et al*. (2011) for weaning to estrous interval and by Chansomboon *et al*. (2009) for WSI; which suggest that environmental factors are more important than genetic factors to explain WSI and FSI variations. Thus, improving management and feeding programs, rather than changes in genetics, can lead to faster economic benefits.

In conclusion, year, parity, breed group, and lactation length were all important factors affecting litter size, WSI, and FSI traits. Greater attention should be given to first-parity sows as they had the smallest litter size and the longest WSI and FSI in comparison with multiparous sows, likely due to higher nutritional requirements for growth and lactation. Breed group differences in litter size and other reproductive traits suggest the importance of establishing an adequate level of crossbreeding under particular management and environmental conditions. Repeatability values were low for the traits studied here, suggesting that environmental factors are more important than genetic factors for explaining reproductive trait variations.

Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

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