Consequences of variation in weaning-to-estrus interval on reproductive performance of swine females

E. Poleze a, M.L. Bernardi b, W.S. Amaral Filha a, Ivo Wentz a, F.P. Bortolozzo a, *

a Universidade Federal do Rio Grande do Sul-UFRGS, Faculdade de Veterinária, Setor de Suínos, Av. Bento Gonçalves, 9090, CEP 91540-000 Porto Alegre, RS, Brazil

b UFRGS, Faculdade de Agronomia, Departamento de Zootecnia, Av. Bento Gonçalves, CEP 91540-000, Porto Alegre, RS, Brazil

Received 26 January 2005; received in revised form 10 January 2006; accepted 7 February 2006

Abstract

Frequency distribution of females according to weaning-to-estrus interval (WEI) was evaluated in a database containing 15,600 breeding records of one Brazilian farm. The consequences of WEI duration on the reproductive performance was evaluated, emphasising on the effect of very short WEI (0 to 2 days). Only females with WEI up to 21 days, lactation length of 13 to 26 days and parity 1 to 8 were included in the analyses. The average WEI was 4.8 days and the percentage of females showing estrus within 2 days after weaning was 6.1%. In both primiparous (PO 1) and multiparous females (PO > 1) those with WEI of 3–5 days showed the lowest return to estrus rate. The highest RER and the lowest FR were observed when estrus occurred on the day after weaning, for primiparous sows, and on the day of weaning, for multiparous sows. In both parity classes, WEI of 0–2, 6–8, 9–12 and 13–18 days resulted in FR lower (P < 0.05) than those observed for WEI of 3–5 days. In PO 1 females, the lowest subsequent litter size (SLS) was observed in those with WEI of 6–8 and 9–12 days (P < 0.05). In PO > 1 females SLS increased significantly from WEI 0–2 to WEI 3–5 days, it decreased in females with WEI of 6–8 days and increased again in females with WEI of 9 to 21 days. A negative effect of WEI on reproductive performance is clear in females with very short WEI (0–2 days) and in those with WEI of 6–12 days.

© 2006 Elsevier B.V. All rights reserved.

Keywords: Weaning-to-estrus interval; Reproductive performance; Return to estrus; Farrowing rate; Litter size

1. Introduction

The weaning-to-estrus interval (WEI) corresponds to the period between the day of weaning (Day 0) and the first day sow is showing standing heat, being part of the normal reproductive cycle of the female. The WEI is one of the main components of non-productive days and may be influenced by lactation length, parity order, litter size, season, nutrition, boar exposure after weaning, genetic, diseases and management (Dial et al., 1992).

In the 1980s, females with lactation length of 5 weeks presented WEI between 11.5 and 20.5 days.
As swine production has been intensified in the last years, this interval reduced to approximately 5–7 days (Koketsu and Dial, 1997; Behan and Watson, 2005). In most modern sow farms, females commonly show estrus between 3 and 5 days postweaning (Vesseur, 1997), with more than 90% returning to estrus by Day 7 postweaning (Belstra et al., 2004; Behan and Watson, 2005).

There is evidence that reproductive performance is influenced by WEI. Wilson and Dewey (1993) observed that females with WEI of 7–10 days had fewer piglets born alive and lower farrowing rate than those with WEI of 3–6 and 11–14 days. Litter size decreased from a WEI of 4 days to a WEI of 8 days and females with a WEI of 6 days had 0.3 piglets lower than those with a WEI of 5 days (Vesseur, 1997). The number of piglets born increased when the WEI became longer than 9–12 days (Wilson and Dewey, 1993), the highest litter size being observed in females with WEI greater than 18 days (Vesseur, 1997).

In a preliminary study, concerning WEI duration, Poleze et al. (2004) observed a great percentage (7.2%) of females showing estrus within 2 days postweaning. In most studies regarding WEI, females with WEI between 0 and 2 days are rarely evaluated individually. They are normally grouped with those showing estrus within 3 or 4 days after weaning (Vesseur, 1997; Weitze et al., 1994; Tantasuparuk et al., 2000, 2001) leading to a lack of information about reproductive performance of females with very short WEI (0–2 days).

Therefore, the objective of the present study was to characterise the frequency distribution of females according to weaning-to-estrus interval and to quantify the consequences of its variability on the reproductive performance, which was evaluated in terms of return to estrus rate, farrowing rate and subsequent litter size.

2. Material and methods

2.1. Selection of data

The database was obtained from a backup of the farm management program PigCHAMP® of one swine production unit. The farm was located in the Midwest Region (Parallel 14°) of Brazil and held a housing capacity of approximately 6000 females. The database corresponded to breeding records of Camorough-22® females of Agroceres PIC® Genetic. The period analysed was from January/2002 to December/2003.

2.2. Parameters of reproductive performance

The detection of estrus was performed with the aid of a sexually mature boar twice daily from the day of weaning onwards. Onset of estrus was considered when the sow presented the first standing response to the back pressure, in the presence of the boar. The females were grouped in 8 classes according to WEI, being 0, 1, 2, 3–5, 6–8, 9–12, 13–18 and 19–21 days.

Return to estrus rate (RER) measured the percentage of return to estrus (regular or irregular) after insemination at the first postweaning estrus. Farrowing rate (FR) measured the percentage of farrowings excluding breeding records corresponding to females that died or that were removed from the herd for non-reproductive reasons. For the subsequent litter size (SLS), the total number of piglets was considered including those born alive, stillborn and mummified.

3. Statistical analyses

The database contained 15,600 breeding records, after excluding the data corresponding to the breeding of gilts, lactation periods shorter than 13 days or longer than 26 days and WEI longer than 21 days. Records concerning the reproductive performance subsequent to the breeding after a return to estrus, abortion or of sows failing to farrow were not analysed. These records were excluded because reproductive performance was not a consequence only of the WEI but also of the additional time each female had due to the first unsuccessful breeding after weaning. Data corresponding to females used as nurse-sows were also excluded from the analyses.

For the analysis, data were separated, according to the parity order (PO), in primiparous (PO 1) and multiparous (PO >1). The data concerning reproductive performance (RER and FR) resulting of different
WEI classes were compared by the Chi-square test. The influence of WEI on the subsequent litter size was analysed using the GLM procedure (SAS, 2000). Lactation length was maintained in the model as a covariate. The least square means were compared by the Tukey–Krammer’s test, with a significance level of 5%.

4. Results

Descriptive statistics of PO, lactation length, WEI and SLS are presented in Table 1. Females showing estrus at 0, 1 and 2 days after weaning represented 1.8%, 1.4% and 2.9% of females, respectively (Table 2). A total of 77.2% of females showed estrus between 3 and 5 days postweaning.

The average RER and FR were 7.6% and 89.6%, respectively. The highest RER and the lowest FR were observed when estrus occurred on the day after weaning, for primiparous sows, and on the day of weaning, for multiparous sows. In both parity classes, females with WEI of 3–5 days showed the lowest RER (Table 2). RER decreased from WEI 0 to WEI 3–5 days, it increased in females with WEI of 6 to 12 days and decreased again in females with WEI of 13 to 21 days. Overall, FR increased from WEI 0 to WEI 3–5 days, it decreased in females with WEI of 6 to 12 days and increased again in females with WEI of 13 to 21 days. In both parity classes, WEI of 0–2, 6–8, 9–12 and 13–18 days resulted in RER higher and FR lower (\( P < 0.05 \)) than those observed for WEI of 3–5 days.

The overall average SLS was 11.2 piglets. The SLS according to WEI and PO is shown in Table 3. In PO 1 females, the lowest SLS was observed in those with WEI of 6–8 and 9–12 days (\( P < 0.05 \)). In PO >1 females, SLS increased significantly from WEI 0–2 to WEI 3–5 days, it decreased in females with WEI of 6–8 days and increased again in females with WEI of 9–21 days.

The WEI of 6–8 and 9–12 days resulted in lower FR, in both primiparous and multiparous sows.

### Table 1
Descriptive statistics of some variables of data analyzed in a commercial Brazilian swine farm

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Means ± S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaning-to-estrus interval</td>
<td>15,600</td>
<td>4.8 ± 2.8</td>
</tr>
<tr>
<td>Parity order</td>
<td>15,600</td>
<td>3.4 ± 1.8</td>
</tr>
<tr>
<td>Lactation length</td>
<td>15,600</td>
<td>17.0 ± 1.4</td>
</tr>
<tr>
<td>Subsequent litter size</td>
<td>13,580</td>
<td>11.2 ± 3.3</td>
</tr>
</tbody>
</table>

### Table 2
Distribution of females, return to estrus rate (RER) and farrowing rate (FR) according to parity order (PO) and weaning-to-estrus interval (WEI)

<table>
<thead>
<tr>
<th>WEI (days)</th>
<th>PO 1 n/n (%)</th>
<th>PO &gt;1 n/n (%)</th>
<th>RER</th>
<th>FR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10/29 (34.5)b</td>
<td>108/249 (43.4)a</td>
<td>16/29 (55.2)cd</td>
<td>122/239 (51.0)bc</td>
</tr>
<tr>
<td>1</td>
<td>16/24 (66.7)a</td>
<td>43/187 (23.0)b</td>
<td>7/24 (29.2)cd</td>
<td>134/183 (73.2)ad</td>
</tr>
<tr>
<td>2</td>
<td>9/43 (20.9)bc</td>
<td>50/407 (12.3)c</td>
<td>30/41 (73.2)bc</td>
<td>326/393 (82.9)bc</td>
</tr>
<tr>
<td>3–5</td>
<td>12,041 (77.2)</td>
<td>462/10,029 (4.6)c</td>
<td>1764/1969 (89.6)a</td>
<td>9104/9764 (93.2)a</td>
</tr>
<tr>
<td>6–8</td>
<td>1752 (11.2)</td>
<td>486/591 (82.2)b</td>
<td>902/1094 (82.4)c</td>
<td>154/192 (80.2)cd</td>
</tr>
<tr>
<td>9–12</td>
<td>296 (1.9)</td>
<td>28/202 (13.9)c</td>
<td>64/91 (70.3)c</td>
<td>182/214 (85.0)bc</td>
</tr>
<tr>
<td>13–18</td>
<td>410 (2.6)</td>
<td>25/226 (11.1)cd</td>
<td>148/177 (83.6)b</td>
<td>114/127 (89.8)jb</td>
</tr>
<tr>
<td>19–21</td>
<td>162 (1.0)</td>
<td>8/130 (6.1)de</td>
<td>27/32 (84.4)ab</td>
<td>114/127 (89.8)jb</td>
</tr>
</tbody>
</table>

Values followed by different letters, in the column, differ (\( P < 0.05 \)).

### Table 3
Subsequent litter sizes according to parity order (PO) and weaning-to-estrus interval (WEI)

<table>
<thead>
<tr>
<th>WEI (days)</th>
<th>PO 1 Litter size</th>
<th>PO &gt;1 Litter size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16 10.6 ± 3.2abc</td>
<td>122 9.9 ± 3.7c</td>
</tr>
<tr>
<td>1</td>
<td>7 10.2 ± 4.2b</td>
<td>134 10.0 ± 3.2c</td>
</tr>
<tr>
<td>2</td>
<td>30 12.0 ± 3.4ab</td>
<td>326 10.7 ± 3.3c</td>
</tr>
<tr>
<td>3–5</td>
<td>1764 10.5 ± 3.2bc</td>
<td>9104 11.5 ± 3.2b</td>
</tr>
<tr>
<td>6–8</td>
<td>486 9.8 ± 3.3d</td>
<td>902 10.6 ± 3.2c</td>
</tr>
<tr>
<td>9–12</td>
<td>64 9.6 ± 3.4d</td>
<td>154 11.8 ± 3.3ab</td>
</tr>
<tr>
<td>13–18</td>
<td>148 11.2 ± 3.2ab</td>
<td>182 11.8 ± 3.6ab</td>
</tr>
<tr>
<td>19–21</td>
<td>27 13.0 ± 2.6a</td>
<td>114 12.4 ± 3.7a</td>
</tr>
</tbody>
</table>

Values followed by different letters, in the column, differ (\( P < 0.05 \)).

Values presented as LS means ± standard deviation.

Farrowing rate was calculated excluding breeding records (\( n = 440 \)) corresponding to females that died or that were discarded for non-reproductive reasons.
Nevertheless, litter size of primiparous sows was reduced due to these two weaning-to-estrus intervals whereas only the WEI of 6–8 negatively affected the litter size of multiparous sows.

The frequency distribution of females according to PO, lactation length within WEI classes is shown in Table 4. Most females of all lactation length classes manifested their estrus within 3–5 days after weaning. More than 30% of primiparous females with short lactation (13–15 days) showed estrus within 6–8 days after weaning.

### Table 4

Percentage of females distributed according to parity order (PO) and lactation length within weaning-to-estrus interval (WEI) classes

<table>
<thead>
<tr>
<th>WEI (days)</th>
<th>PO 1</th>
<th>Lactation length (days)</th>
<th>PO &gt;1</th>
<th>Lactation length (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13–15</td>
<td>16–19</td>
<td>20–22</td>
<td>23–26</td>
</tr>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.6</td>
<td>3.7</td>
<td>8.0</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.9</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
<td>1.3</td>
<td>1.2</td>
<td>6.0</td>
</tr>
<tr>
<td>3–5</td>
<td>59.2</td>
<td>65.8</td>
<td>76.3</td>
<td>70.0</td>
</tr>
<tr>
<td>6–8</td>
<td>30.7</td>
<td>20.8</td>
<td>8.6</td>
<td>10.0</td>
</tr>
<tr>
<td>9–12</td>
<td>2.8</td>
<td>3.2</td>
<td>2.9</td>
<td>2.0</td>
</tr>
<tr>
<td>13–18</td>
<td>4.1</td>
<td>6.4</td>
<td>5.3</td>
<td>2.0</td>
</tr>
<tr>
<td>19–21</td>
<td>0.9</td>
<td>1.0</td>
<td>1.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

5. Discussion

The percentage of females showing estrus up to 2 days after weaning (6.1%) is higher than that reported previously for females with WEI up to 3 days (Vesseur, 1997; Weitze et al., 1994). The percentage of females showing estrus up to 3 days has ranged from 0.6% (Vesseur, 1997) to 3.2% (Weitze et al., 1994) and that up to 4 days days ranged from 4.5% to 24.6% (Vesseur, 1997; Tantasuparuk et al., 2000, 2001).

Some females could show estrus during lactation or soon after weaning (0, 1 and 2 days) when frequency and intensity of suckling are altered (Stevenson and Davis, 1984). Failure in the suckling stimuli intensity, as well as reduced frequency, could gradually unblock hypothalamus allowing GnRH release, anticipating the onset of cyclic ovarian activity after weaning (Stevenson and Britt, 1981). A low suckling stimulus also occurs when there are few or smaller pigs been nursed, aspects observed mainly in procedures as intermittent suckling, split-weaning or utilisation of nurse-sows. These conditions could contribute for the precocious onset of estrus postweaning or lead females to show lactational estrus (Gerritsen et al., 2005), mainly when they receive smaller or wasting piglets (Patterson and Pearce, 1994; Tsuma et al., 1995). In the present study, however, split-weaning was not performed and females used as nurse-sows were excluded from the analysis, showing that these two management procedures could not be the responsible for the precocious onset of estrus after weaning.

Overall, farrowing rates of females with very short WEIs (0–2 days) were compromised and those observed in females with WEI of 0 and 1 day were below of those commonly observed in swine farms. Vesseur (1997) also reported a lower farrowing rate for primiparous females with WEI of 0–3 days in comparison to those with WEI of 5 days but they had a low number of females within this WEI class. In the present study, in addition to the farrowing rate, the subsequent litter size of multiparous females with very short WEI (0–2 days) was also compromised. When compared to WEI of 3–5 days, the subsequent litter size was not affected in primiparous sows showing estrus within 2 days after weaning. Nevertheless, because of the low number of farrowed primiparous females with WEI of 0–2 days, no sound conclusions can be drawn concerning the litter size of these females.

The reason by which females with very short WEI intervals have a reduced reproductive performance is
Gaustad-Aas et al. (2004) observed an overall farrowing rate of 69.5% in females served during lactation, pointing out that decreased reproductive performance could be related to incomplete uterine involution and hormonal imbalance associated with deficient follicular development and ovulation. The interval to estrus postweaning will depend on the stage of follicular development, which begins before sow is weaned (Lucy et al., 2001). Theoretically, in the present study, females showing estrus on the weaning day or soon after had a group of follicles completing their development during lactation. It is not known if health of these follicles that grew under a hormonal environment influenced by suckling stimuli could be compromised and therefore affecting the reproductive performance of females with very short WEI (0–2 days). It is worth reminding that in females detected in estrus on Days 0 and 1 postweaning, the onset of estrus could have been missed. Thus, some of these females could have been inseminated in an inadequate insemination–ovulation interval that could explain the high return to estrus observed in females with very short WEI.

The reduced fertility associated to very short WEI could also be due to a greater incidence of ovarian cysts in sows with a weaning-to-estrus interval shorter than 3 days, as observed by Castagna et al. (2004). The development of multiple, large follicular cysts was also observed in three of the five females showing estrus on Days 1–2 postweaning, in the study of Belstra et al. (2004). A greater rate of return to estrus has been reported in females with ovarian cysts if compared to sows without cysts (Castagna et al., 2004).

Behan and Watson (2005) observed that the delaying of the boar stimulus until Day 4 after weaning resulted in farrowing rate and litter size higher than with the standard method of exposure to the boar since the day of weaning. When the beginning of boar exposure was delayed to Day 4 after weaning, there were no females served Days 0–3, what could explain the better results of this management. These authors (Behan and Watson, 2005) believe that the benefit of delaying the boar exposure may be due to artificial insemination being timed more closely to ovulation, to a more certain identification of true estrus and/or improved sperm transport in the sow.

The reduction in the farrowing rate or litter size observed in females with WEI between 6 and 12 days confirms other reports, although the day exact for this reduction is a little variable among studies (Wilson and Dewey, 1993; Vesseur, 1997; Steverink et al., 1999; Tantasuparuk et al., 2000; Tummaruk et al., 2001; Bracken et al., 2003). The mechanisms regulating the effects of WEI on farrowing rate and litter size remain to be determined, but all the factors that are likely to modulate the suckling stimulus and metabolic condition of the sow may influence WEI, subsequent ovulation and farrowing rate (Quesnel, 2001). Sows with short intervals from weaning to ovulation had larger follicles by Day 3 after weaning (Bracken et al., 2003). According to Yang et al. (2000), increasing the size of the preovulatory pool of follicles may increase ovulation rate, whereas embryonic survival may be increased by improving quality of follicles ovulated. Patterson et al. (2001) observed a negative correlation of WEI with the ovulation rate and Willis et al. (2001) observed that oestradiol concentration in day one postweaning was negatively correlated with WEI and positively correlated with embryo number, suggesting that incidence of atretic or poor quality follicles as WEI increases could contribute to the decreased litter size.

Soede et al. (2001) explain the decrease in litter size and farrowing rate with an increase in WEI from 3 to 7–12 days by a lower ovulation rate and lower embryo survival which are probably carry over effects from disturbed follicular development during or after lactation and or by poorer fertilization rates due to a suboptimal timing of insemination. According to Soede and Kemp (1997), an increase between 3 and 8 days in WEI would be associated with reduction of interval between the onset of estrus and ovulation, where females with longer WEI would have a shorter interval between onset of estrus and ovulation. In this way, it increases the chance that first artificial insemination would be postovulatory in females with longer WEI. It is uncertain, however, that the time of insemination in relation to the time of ovulation is the only reason for the lower reproductive performance of sows with WEIs between 6 and 12 days, because both duration of estrus and estrus-to-ovulation interval tend to decrease as weaning-to-estrus interval increases from 3 to 6 days (Soede and Kemp, 1997) but they did not decrease further as WEI increased from 6 to 7 or
more days (Steverink et al., 1999; Belstra et al., 2004). Furthermore, duration of estrus and onset of estrus-to-ovulation interval can vary considerably among different farms, within an individual farm over time, because farm-specific factors can influence the range over which WEI has an inverse relationship with duration of estrus and onset of estrus-to-ovulation interval (Belstra et al., 2004).

The reason by which reproductive performance of females with WEIs between 6 and 12 days is depressed can also be related to the fact that females with a greater percentage of body weight loss are candidates to have a WEI greater than the conventional duration. In the study of Thaker and Bilkei (2005), females with lactation weight losses of 11–15%, 16–20% and >20% were those having weaning-to-service intervals near to 6, 7 and 10 days, respectively. In both primiparous and multiparous sows, >10% lactation weight losses significantly depressed subsequent farrowing rates and litter size. Zak et al. (1997) observed that primiparous sows with a feed restriction to 50% from Days 22 to 28 of lactation had increased weaning to estrus interval, decreased IGF-I level, lower ovulation rate and embryo survival when compared to sows fed to appetite. An inadequate nutrient intake during lactation influences the metabolic state of the sow before the final growth of preovulatory follicles which is a critical determinant of subsequent fertility. Presumably, the decreased quality of both follicles and oocytes, due to the negative energy balance, might contribute to the decreased litter size (Yang et al., 2000; Thaker and Bilkei, 2005). Slower developing cohorts of follicles in sows with long intervals to estrus may be less healthy and, thus, lead to lower conception rate and litter size (Bracken et al., 2003). In the present study, short lactation resulted in higher percentage of estrus at 6–8 days in comparison to longer lactation periods, in primiparous sows. Perhaps, the reduced reproductive performance of females with WEI of 6–12 days may be partly explained by the fact that short lactations are associated with the transition phase of reproductive system recovery. This phase lasts until about Day 14 of lactation and it is characterised by the presence of small follicles, low levels of FSH, LH and estrogen (Britt, 1996). Furthermore, females with short lactations have a shorter period for their uterine involution.

The higher litter size observed in females with WEI of 19–21 days agrees with the increase of litter size in females with WEI >18 days (Vesseur, 1997). Litter size has also been reported to increase as WEI increased from Days 10 to 20 (Tummaruk et al., 2001). The reason for this increase could be mainly related to the extra-period that these females had to recover of the catabolism suffered during lactation and to the longer period for uterine involution (Soede et al., 2001). Soede et al. (2001) also comment that females with longer WEI could have showed better reproductive performance for having been inseminated in a possible second estrus postweaning. Females that concentrated WEI later postweaning (18 to 21 days) could have showed estrus during lactation or soon after weaning without having been detected.

6. Conclusions

Farrowing rate is compromised in females that show estrus within 0–2 days and 6–12 after weaning. The litter size is reduced in primiparous females with WEI of 6–12 days whereas it is compromised in multiparous females showing estrus within 0–2 days and 6–8 days after weaning.

References


