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Environmental and sow-related factors affecting the duration of farrowing

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A B S T R A C T

A short duration of farrowing is important for piglet survival as a delay can increase the number of stillborn. Many factors may affect the duration of farrowing, including breed, age of the sow, length of gestation, number of piglets born, housing (CRATE vs. PEN), body condition of the sow and state of constipation. The aim of the present study was to investigate these factors and how they interact with each other and thus increasing the risk of prolonged farrowing. The total duration of farrowing and average piglet birth interval were recorded in 172 sows from two herds (HERD-1, n = 76; HERD-2, n = 96). Back-fat measurements and intestinal activity (based on the mean of a constipation index) were measured in all 172 sows. The total duration of farrowing was 272 ± 152 min (mean ± SD, n = 172): 301 ± 165 min (n = 115) in the CRATE group and 212 ± 95 min (n = 57; P < 0.05) in the PEN group. The average piglet birth interval was 26 ± 25 min (mean ± SD, n = 172): 29 ± 29 min (n = 115) in the CRATE group and 19 ± 10 min (n = 57; P < 0.05) in the PEN group. Housing (P < 0.05), stillborn (P < 0.001), back-fat average (P < 0.001) and constipation index (P < 0.05) significantly correlated with the duration of farrowing.

In conclusion, allowing the sow to move freely before farrowing, reducing the constipation state and avoid excessive fattening during late pregnancy all appear to be key factors in shortening farrowing time and reducing perinatal mortality.

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1. Introduction

At farrowing sows are expected to give birth to several piglets in a relatively short period of time. Problems during farrowing have serious implications for both the economic results of the herd and for the health of the animals. The piglet mortality rate during farrowing varies (Zaleski and Hacker, 1993) and depends on several factors (Herpin et al., 1996) but high number of stillborn piglets negatively affects the production outcome and might also represent an animal welfare issue. In addition, sows can be affected by problems at farrowing, such as dystocia and infections which can reduce production and jeopardise their health (Cowart, 2007).

One of the factors that can play a key role during farrowing, with regard to the survival of piglets and the sow’s health, is its duration. Previous studies have demonstrated that the duration of farrowing and the number of stillborn are directly connected (Zaleski and Hacker, 1993; Van Dijk et al., 2005) and evidence also suggests that a longer farrowing period can affect the health of the sow until early lactation (Martineau et al., 1992; Herpin et al., 1996; Van Dijk et al., 2005).

At farrowing the sow undergoes substantial hormonal and metabolic changes during a very short period of time (Algers and Uvnás-Moberg, 2007). Consequently, farrowing is easily disturbed by factors within and around the sow. Many factors, such as, high parity, long length of gestation...
and high number of piglets born and also some breeds may negatively influence the duration of farrowing (Stanton and Carroll, 1974; Cronin et al., 1993; Farmer and Robert, 2002). Housing has also been shown to influence the duration of farrowing. In our previous study, sows in cages had a longer duration of farrowing and showed lower levels of oxytocin than did those housed in pens (Oliviero et al., 2008). In that study, an environment permitting more opportunities for sows to express their nest-building behaviour seemed to shorten the duration of farrowing.

Very limited data are available on the possible effects of other factors, such as the sow’s body condition, on the duration of farrowing. Moreover, feed intake and intestinal activity undergo major changes around farrowing, when sows are often constipated (Oliviero et al., 2009). Previous research has already shown, constipation is associated with udder infections in sows during early lactation (Hermansson et al., 1978; Smith, 1985; Persson, 1996) and may cause pain or discomfort, as well as affect the duration of farrowing (Cowart, 2007).

The aim of the present study was to investigate some of the main factors believed to affect the duration of farrowing, including both sow-related factors and factors related to management of the sow, such as housing, sow body condition and constipation. The aim of this experiment was to study how these factors interact and therefore pose a risk for prolonged farrowing.

2. Materials and methods

2.1. Animals and management

We performed the experiment using sows in a commercial sow-pool piggery system (Peltoniemi et al., 2009). This system consisted of a nucleus herd, where the sows were inseminated and then managed in a loose housing pregnancy unit in groups of 40 sows each. In these loose housed units sows were fed in individual stalls. At approximately day 95 of gestation the sows were sent to farrow in four satellite herds where they stayed until week 4 of lactation (Cowart, 2007). Descriptive statistics of sows in CRATES and in PENS.

<table>
<thead>
<tr>
<th>Variables</th>
<th>CRATE (n = 115)</th>
<th>PEN (n = 57)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity</td>
<td>4.3 ± 1.8</td>
<td>4.5 ± 1.8</td>
<td>0.58</td>
</tr>
<tr>
<td>Total born</td>
<td>12.7 ± 3.2</td>
<td>12.7 ± 2.8</td>
<td>0.96</td>
</tr>
<tr>
<td>Stillborn</td>
<td>1 ± 1.5</td>
<td>0.4 ± 0.7</td>
<td>0.007</td>
</tr>
<tr>
<td>Gestation length</td>
<td>116.1 ± 12</td>
<td>115.9 ± 12</td>
<td>0.14</td>
</tr>
<tr>
<td>Back-fat average</td>
<td>14.6 ± 3.7</td>
<td>14.4 ± 3.4</td>
<td>0.44</td>
</tr>
<tr>
<td>Constipation index</td>
<td>1.9 ± 0.6</td>
<td>2.1 ± 0.5</td>
<td>0.21</td>
</tr>
</tbody>
</table>

In our study, we used sows farrowing in only two of the satellite herds (HERD-1 and HERD-2) during 18 consecutive months for a total of 11 replicates: 5 in HERD-1 (n = 19; n = 16; n = 15; n = 10; n = 16; parity = 4.4 ± 1.7) and 6 in HERD-2 (n = 16; n = 16; n = 14; n = 16; n = 19; n = 15; parity = 4.4 ± 1.9). All sows were Finnish Yorkshire × Finnish Landrace inseminated with the semen of nine different boars (eight were Finnish Hampshire × Finnish Duroc and one was pure Finnish Hampshire). In HERD-1 (n = 76), sows were housed only in farrowing crates (80 cm × 210 cm) with semi-slatted floors (CRATE); feed was served twice daily (at 09:00 and 17:00), and the ambient temperature ranged from 18 to 25 °C. In HERD-2 (n = 96), sows were housed in the same room in farrowing crates (80 cm × 210 cm, n = 39) with semi-slatted floors (CRATE) and in farrowing pens (220 cm × 220 cm, n = 57) with semi-slatted floors and sawdust bedding (PEN); feed was served twice daily (at 12:00 and 19:00), and the ambient temperature ranged from 19 to 24 °C. In both herds, the crates and pens were cleaned every morning before feeding time (Table 1). Both herds used a commercial diet for late pregnancy containing 16.8% crude protein, 6.8% crude fat and 3.8% crude fibre (Jmetys-Pekoni®, Suomen Rehu Ltd., Finland). In both herds sows were randomly assigned to the study as they entered the herd. Human assistance (palpation, extraction of piglets) and/or use of oxytocin at parturition were exclusion criteria from the study.

2.2. Collection of data

A digital video recorder (AVC787, AV Tech., Taiwan) connected to infrared cameras (TS-6030PSC, AV Tech., Taiwan) allowed us to continuously record all the sows without the need for alternative sources of light even during the night when the room lights were off. Every sow in the study was individually monitored with an infrared camera placed on the roof, thus allowing a 360° view of the pen or crate. After each replicate, we observed the video and recorded the total duration of farrowing (TDF) for every sow as the time in minutes from the first to the last piglet born. In addition, we recorded the piglet birth interval average (PBI) as the time in minutes between each piglet born and the number of piglets born alive and stillborn. A piglet was defined as stillborn if after birth it showed no signs of breathing or movement (evaluated by observation of the video). Using the herd database software (WinPig®, AgroSoft Oy, Seinäjoki, Finland), we collected information regarding parity, the gestation length (from day of first insemination to the day of farrowing) and the boar used for insemination.

We took two measurements of the back-fat layer in each sow using a digital back-fat indicator (Renco LeanMeater®, Renco Corporation, Minneapolis, MN, USA). The back-fat digital indicator probe was placed on the back of the sow at the level of the last rib, 6–7 cm from one side of the backbone. Two consecutive measurements in the same spot were taken, and averaged to obtain a more accurate final value. The first measurement was taken between day 85 and day 95 of gestation in the nucleus herd, and the second measurement at farrowing in the satellite herd (within 2 days before or after farrowing). The two measurements were averaged to create a variable called the back-fat average (BFA).

We measured the intestinal activity of the sows from 5 days before to 5 days after farrowing by evaluating daily the quality of their faeces, as previously described by Oliviero et al. (2009). Every morning before the daily cleaning, the faeces of each sow were ranked by visual qualitative evaluation. A trained farmer assigned a score value ranging from 0 to 5: 0 (absence of faeces), 1 (dry and pellet-shaped), 2 (between dry and normal), 3 (normal and soft, but firm and
2.3. Statistical analysis

Total duration data for farrowing and piglet birth interval average were transformed with a log10 function to normalise their distribution. We analysed the factors affecting the log10-transformed total duration of farrowing (TDF-log) and the log10-transformed piglet birth interval (PBI-log) average using regression analysis. In this univariate analysis, TDF-log and PBI-log were the dependent variables and the factors analysed included housing (CRATE vs. PEN), parity, total born, number of stillborn, number of liveborn, gestation length, BFA, CI, herds, replicates and boars. Based on the results from the univariate model, all factors that approached significance ($P < 0.05$) were included as independent variables in a multivariate analysis; non-significant variables ($P > 0.05$) were excluded from this multivariate model. The initial multivariate model for TDF-log included housing (CRATE vs. PEN), total born, number of stillborn, BFA, CI, herds and replicates. After a stepwise elimination procedure, the final multivariate model for TDF-log included housing (CRATE vs. PEN), number of stillborn, BFA, CI and herd.

The initial multivariate model for the PBI-log included housing (CRATE vs. PEN), total born, number of liveborn, number of stillborn, BFA, CI, herd, replicates and boars. The partial correlation and interaction between all the variables were tested and found to be non-significant. The detailed statistical models appear in Tables 2 and 3. Statistical analysis was performed with the SPSS programme, version 15.0 (SPSS Inc., Chicago, IL, USA).

3. Results

The total duration of farrowing was 272 ± 152 min ($\text{mean} \pm \text{SD}, n = 172$), 301 ± 165 min ($n = 115$) in the CRATE group, and 212 ± 95 min ($n = 57$; $P < 0.05$) in the PEN group. The piglet birth interval average was 26 ± 25 min ($\text{mean} \pm \text{SD}, n = 172$), 29 ± 29 min ($n = 115$) in the CRATE group and 19 ± 10 min ($n = 57$; $P < 0.05$) in the PEN group.

Parity of the sows was 4.4 ± 1.8 (range from 1 to 8, $n = 172$), and their average total born was 12.7 ± 3 piglets ($n = 172$), with 0.8 ± 1.3 stillborn ($n = 172$). The average gestation length was 116 ± 1 days (range from 112 to 120 days, $n = 172$). The BFA was 14.5 ± 3.6 mm (range from 7.5 to 24.5, $n = 172$), and the average CI score was 2 ± 0.6 (range from 0.3 to 3, $n = 172$). Descriptive statistics restricted to PEN and CRATE sows are summarised in Table 1. Housing in crate ($P < 0.05$), higher number of stillborn ($P < 0.001$), higher BFA values ($P < 0.001$) and lower CI ($P < 0.01$) affected negatively TDF. The piglet birth interval average was negatively affected by higher number of total born ($P < 0.001$) and higher BFA values ($P < 0.01$).

In Fig. 2, all the sows falling in areas C and D have a normal duration of farrowing (<300 min), whereas those falling in areas A and B farrowed longer than normal (>300 min). Many of the constipated sows (<1.9 CI) fall in area A, whereas most of the unconstipated sows (>1.9 CI) fall in area D. In Fig. 3, all the sows falling in areas C and D have normal duration of farrowing (<300 min), whereas those falling in areas A and B farrowed longer than normal (>300 min). Most of the fatter sows (>17 mm of back-fat) fall in area B, whereas most of the thinner sows (<17 mm of back-fat) fall in area C.

4. Discussion

The results of the present study confirmed some of the findings of our previous study (Oliviero et al., 2008) regarding the effect of housing on the duration of farrowing. Moreover, we also found that the duration of farrowing is longer in sows with higher back-fat thickness and more severe constipation.

Limiting the possibility of the sow to move around seems to be an important factor affecting the duration of farrowing in contrast to the findings reported by Fraser et al. (1997). Interestingly, the space needed to avoid prolonged farrowing is surprisingly small. In this study, the PEN group of sows were housed in 220 cm × 220 cm pens. The process of parturition may be beneficial if the sow is allowed to move more freely and to turn around, movements that are impossible if she is caged.
The complete linear regression model for the piglet birth interval average, log$_{10}$ transformed (PBI-log) as a dependent variable.

<table>
<thead>
<tr>
<th>Variables</th>
<th>$P$</th>
<th>Inclusion in the multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>0.01</td>
<td>Included</td>
</tr>
<tr>
<td>Parity</td>
<td>0.18</td>
<td>Excluded</td>
</tr>
<tr>
<td>Total born</td>
<td>0.001</td>
<td>Included</td>
</tr>
<tr>
<td>Number of liveborn</td>
<td>0.01</td>
<td>Included</td>
</tr>
<tr>
<td>Number of stillborn</td>
<td>0.05</td>
<td>Included</td>
</tr>
<tr>
<td>Gestation length</td>
<td>0.02</td>
<td>Included</td>
</tr>
<tr>
<td>Back-fat average (BFA)</td>
<td>0.0001</td>
<td>Included</td>
</tr>
<tr>
<td>Constipation index (CI)</td>
<td>0.005</td>
<td>Included</td>
</tr>
<tr>
<td>Herd</td>
<td>0.01</td>
<td>Included</td>
</tr>
<tr>
<td>Replicate</td>
<td>0.01</td>
<td>Included</td>
</tr>
<tr>
<td>Breed of sire</td>
<td>0.17</td>
<td>Excluded</td>
</tr>
</tbody>
</table>

### Table 3
The complete linear regression model for the piglet birth interval average, log$_{10}$ transformed (PBI-log) as a dependent variable.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Final model</th>
<th>Stepwise 4</th>
<th>Stepwise 3</th>
<th>Stepwise 2</th>
<th>Stepwise 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>0.07</td>
<td>0.18</td>
<td>0.23</td>
<td>0.24</td>
<td>0.29</td>
</tr>
<tr>
<td>Total born</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Number of stillborn</td>
<td>0.08</td>
<td>0.04</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Back-fat average (BFA)</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Herd*</td>
<td>0.66</td>
<td>0.52</td>
<td>0.39</td>
<td>0.12</td>
<td>0.05</td>
</tr>
<tr>
<td>Constipation index (CI)</td>
<td>–</td>
<td>0.19</td>
<td>0.13</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Number of liveborn</td>
<td>–</td>
<td>–</td>
<td>0.29</td>
<td>0.12</td>
<td>0.05</td>
</tr>
<tr>
<td>Replicate</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.73</td>
<td>0.74</td>
</tr>
<tr>
<td>Gestation length</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.89</td>
</tr>
</tbody>
</table>

* Herd forced into the model.

The study was conducted on a satellite herd in which sows are normally caged and the pens were obtained by opening and fixing the bars of the cages so that the sow could move freely and turn around. After the end of farrowing, the bars were eventually closed. These findings also imply practical uses, since some herds could convert their caged pens to open ones at least for the period before farrowing to benefit from an improved parturition process. If necessary, they can be closed after the end of farrowing to protect the piglets. It is also important to consider that the PEN sows had sawdust bedding, while the CRATE sows did not. Its availability for the PEN sows may also have played an important role in shortening the duration of farrowing (Cronin et al., 1993).

Results on the average duration of farrowing obtained in previous studies, for sows housed in pens or crates, ranged from 156 to 262 min (Randall, 1972; Madec and Leon, 1992; Van Dijk et al., 2005). In our study, the range among PEN-housed sows was in line with the range found in previous studies. On the other hand, the CRATE-housed sows had on average 89 min longer farrowing periods than did the sows in the PEN group, with a duration falling out of the above-mentioned range. We found a similarly longer duration of farrowing in modern swine production (Van Dijk et al., 2005). In our study, the range among PEN-housed sows was in line with the range found in previous studies. On the other hand, the CRATE-housed sows had on average 89 min longer farrowing periods than did the sows in the PEN group (Fig. 1). However, any interaction between parity and housing would be more likely to be seen with a larger sample size. It is therefore feasible that the effect of housing on the duration of farrowing would be larger among older parity sows. One explanation could be that old sows are usually bigger than young sows, which may make movements in the cage more difficult, especially prior to farrowing when the sow is more active due to the nest-building behaviour. In our study crated sows at parity 5 and 6 had on average 2.1 mm ticker back-fat value compared to the caged sows of lower parity.

Stillborn births and the duration of farrowing were highly correlated, as previous studies (Van Dijk et al., 2005) have shown, but it is difficult to establish which of these two factors is the primary cause of the other. In our study, sows with a duration of farrowing shorter than 300 min ($n = 114$) had $1.5 \pm 1.8$ (mean $\pm SD$) stillborn piglets, whereas sows with a duration of farrowing shorter than 300 min ($n = 58$) had $0.4 \pm 0.8$ stillborn piglets ($P < 0.001$). On this basis, recalling available data on the average duration of farrowing in modern swine production (ranging between 156 and 262 min), farrowings lasting more than 300 min (5 h) should be considered longer than average and a risk for increased perinatal mortality.

We found that the more constipated sows were, the longer their farrowings-independent of housing. Constipation is a common state around farrowing (Tabeling et al., 2003; Oliviero et al., 2009) and can worsen from low fibre...
content and or sudden changes in ingredients of the diet. In our study, sows with a constipation index lower than 1.9 had a longer duration of farrowing (343 ± 180 min; n = 72) than did sows with a constipation index higher than 1.9 (219 ± 98 min; n = 100; P < 0.001). The correlation between the constipation index and the duration of farrowing is shown in Fig. 2. Since severely constipated sows can have great amounts of hard faeces in the large intestine and rectum, this solid mass may create a physical obstacle during birth by pressing on the birth canal, thus resulting in a more difficult expulsive stage (Cowart, 2007). The discomfort and pain associated with such constipation may also influence the hormonal pattern of parturition.

Studies have found that opioids inhibit oxytocin during parturition (Bicknell and Leng, 1982; Douglas et al., 1995; Brown et al., 1999). Therefore, pain due to prolonged constipation could promote the release of opioids and consequently, a lower level of oxytocin resulting in less effective expulsive contraction of the uterus. Another theory suggests that a constipated gut may leak endotoxins into the circulation due to a break down of the gut barrier (Smith, 1985; Martineau et al., 1992). These endotoxins may then interfere with the endocri ne regulation of farrowing. These two hypotheses need further investigation to determine whether constipation may indirectly influence the hormonal pattern around farrowing.

The level of back-fat affected the duration of farrowing (Fig. 3) even though the sows used in this study were not particularly fat. The overall back-fat average was 14.5 ± 3.6 mm, which is in line with that found in most Finnish sow-pool systems (Oliviero et al., 2009). Sows with a back-fat average higher than 17 mm had an average dura-

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**Fig. 1.** Average duration of farrowing (with SD bars) among different parities in the PEN-housed and CRATE-housed groups of sows (descriptive data from HERD-1 and HERD-2).

**Fig. 2.** Individual sows plotted by constipation index (CI) and the duration of farrowing. Low CI index values indicate constipated sows, while high CI values indicate sows with normal faeces. The horizontal dashed line discriminates prolonged farrowing (>300 min; A, B); the vertical dotted line discriminates sows with constipation (A, C). The solid regression line represents a negative relationship between the constipation index and the duration of farrowing.
Fig. 3. Individual sows plotted by back-fat average and the duration of farrowing. The horizontal dashed line discriminates prolonged farrowing (>300 min; A, B); the vertical dotted line discriminates the fatter sows (B, D). The solid regression line represents a positive relationship between the back-fat average and the duration of farrowing.


The duration of farrowing of 385 ± 197 min (n = 48), whereas those with a back-fat average of less than 17 mm had an average duration of farrowing of 230 ± 103 min (n = 124; P < 0.001). A higher level of fat is known to affect lipid-soluble steroids, and especially the progesterone:oestrogen ratio, which in turn is known to affect oxytocin receptor activation (McCracken et al., 1999; Russell et al., 2003). Abnormalities due to oxytocin receptor activation may weaken the expulsive phase of parturition. A decline in progesterone and a concomitant increase in the oestrogen profile should occur 36–24 h prior to parturition (Cowart, 2007) but we observed a delayed decline in progesterone beyond day 1 after parturition in a number of our trial sows (Oliviero et al., 2008), a delay that may be linked to obesity and the prolongation of parturition. If so, progesterone bound to fat may be too stable to promptly react to CL regression. Another hypothesis could be that fat sows have more adipose layers around the birth canal (Cowart, 2007), thereby reducing the diameter of the birth canal, which can create a physical obstacle to birth during the expulsive phase with delayed farrowing.

In conclusion, allowing the sow to move freely before farrowing, thereby reducing constipation and avoiding the excessive fattening of the sow during late gestation, all these three seem to be key factors in shortening farrowing time and thus reducing perinatal mortality.

Acknowledgments

The authors wish to thank farmers Jari Ollikkala, Unto Forsgren and Seppo Tuomi for allowing us to run the experiment in their herds. We also express our thanks to Suomen Rehu Oy for partially funding this study.

References