Effects of late introduction of sows to two farrowing environments on the progress of farrowing and maternal behavior

L. J. Pedersen1 and T. Jensen

Institute of Animal Health, Welfare and Nutrition, Faculty of Agricultural Sciences, University of Aarhus, 8830 Tjele, Denmark

ABSTRACT: To evaluate the effect of late introduction to farrowing pens on the progress of farrowing and maternal behavior, 20 primiparous and 20 multiparous sows were allocated randomly to 1 of 2 treatments: 1) early introduction to pen (EP, n = 20) and 2) late introduction to pen (LP, n = 20). To evaluate the difference between loose-housed sows and crated sows when introduced late to the farrowing environment, a third treatment was included: late introduction to farrowing crate (LC, n = 20). Sow behavior and piglet birth intervals were recorded using video recordings from 16 h before the birth of the first piglet (BFP) until 48 h after BFP. Behavioral data were analyzed using PROC MIXED in SAS and the percentage of stillborn piglets and the response of the sow to piglet scream were analyzed using PROC GENMOD in SAS. Before farrowing (16 to 3 h before BFP), sows introduced late to pens had more postural changes per hour than sows introduced early to pens (LP = 12.7, EP = 8.9; P = 0.04), whereas there were no differences between sows introduced late to crates and sows introduced late to pens (LC = 14.2, LP = 12.7; P = 0.53). Interbirth interval (P = 0.04), variation in the interbirth interval (P = 0.01), and percentage of stillborn piglets (P = 0.003) were affected by an interaction between parity and treatment. In multiparous sows there were no differences between treatments (P > 0.18) either in the progress of farrowing or in the percentage of stillborn piglets. For primiparous sows, there were no differences (P > 0.22) between sows that were introduced late to pens and sows that were introduced early to pens. Primiparous sows that were introduced late to crates compared with pens had longer interbirth intervals (LC = 29 ± 4.9 min, LP = 16 ± 2.9 min; P = 0.02), a greater variation of these intervals (LC = 35 ± 8.3 min, LP = 16 ± 3.6 min; P = 0.006), and a greater percentage of stillborn piglets (LC = 21%; 95% confidence interval ranging 14 to 30%, LP = 5%; 95% confidence interval ranging from 2 to 12%; P = 0.004). After farrowing, neither postural changes, time spent in lateral lying, number of near-crushing situations, nor the response to piglet scream test were affected by treatment (P > 0.09). When sows and gilts were introduced late to farrowing pens, neither progress of farrowing nor maternal behavior of importance for piglet crushing was influenced. However, crating primiparous sows that were introduced late to the farrowing environment compared with pen housing had detrimental effects on the progress of farrowing and the percentage of stillborn piglets.

Key words: environment, farrowing pen, maternal behavior, sow, stillborn piglet

INTRODUCTION

In intensive pig production sows are often moved to the farrowing unit close to the time of farrowing. This is because of a combination of increased weaning age and increased litter size leading to greater use of foster sows that nurse 2 litters in succession. Thus, some farrowing crates are occupied for a longer period and consequently there will not be room for the next batch of sows. To move sows immediately before farrowing may be stressful, with potential negative effects on the progress of farrowing and maternal behavior (Lawrence et al., 1997). Because maternal behavior and neonatal piglet viability is considered of great importance for early piglet survival when sows are kept loose, production success may be particularly sensitive to such management procedures in loose-housed sows. When kept under natural conditions, sows will seek isolation and initiate nest-building 2 to 3 d before farrowing (Jensen, 1986). Thus, sows introduced late to the farrowing housing begin seeking isolation while still in the gestation unit. The lack of an outlet for this strong motivation may also constitute a stressor, interfering with
aspects of maternal behavior of importance for early piglet survival such as nesting behavior and carefulness when lying down (Andersen et al., 2005; Pedersen et al., 2006). Present knowledge indicates that moving sows shortly before farrowing may interfere with the progress of farrowing and other aspects of maternal behavior, thereby reducing piglet survival. Such a relationship may particularly be important when sows are housed loose in pens, where the impact of piglet viability and maternal behavior on piglet survival seems greater. The aims of the present study were 1) to investigate the effect of late introduction to farrowing pens on the progress of farrowing and maternal behavior and 2) to evaluate differences between penned and crated sows in maternal behaviors.

MATERIALS AND METHODS

Animals, Housing, and Treatment

All procedures involving animals were approved by the Danish Animal Experiments Inspectorate in accordance with the Danish Ministry of Justice Law no. 382 (June 10, 1987) and Acts 333 (May 19, 1990), 726 (September 9, 1993), and 1016 (December 12, 2001).

Sixty sows (Landrace × Yorkshire) were used in a randomized complete block design with 2 blocks. In block 1 the sows were primiparous and in block 2 the sows were multiparous (2.2 ± 1.1 litters, mean ± SD). Within blocks, sows were randomly distributed into 3 treatments. To evaluate the effect of late introduction to farrowing pens on the progress of farrowing and maternal behavior, 20 primiparous and 20 multiparous sows were allocated randomly to 1 of 2 treatments: 1) early introduction to pen (EP; n = 20) and 2) late introduction to pen (LP; n = 20). To evaluate the difference between loose-housed sows and crated sows when introduced late to the farrowing environment, a third treatment was included: late introduction to farrowing crate (LC; n = 20). In LC and LP, sows were moved from the gestation pen to the farrowing environment on d 114 of pregnancy, whereas in EP, the sows were moved from the gestation pen to the farrowing pen on d 95 of pregnancy, except the first 6 sows that were moved on d 105 of pregnancy. The reason for changing the day of introduction from d 105 to d 95 was that it allowed for additional sampling of the time taken to adjust to the new environment (data not reported here). Initial analysis showed no differences in any response variables between the 2 days of introduction. Thus, the 2 treatments were treated as 1 throughout the paper.

The experiment was conducted from February to October 2005, at the experimental herd of Research Center Foulum (Tjele, Denmark). Sows were walked a distance of 100 m from the gestation unit to the farrowing unit in batches of 6 sows approximately weekly. They were moved between 1000 and 1100 h. Each farrowing unit comprised between 20 and 28 farrowing pens or crates in an environmentally controlled building. The room temperature was kept constant around 20°C throughout the experiment. Farrowing pens for loose-housed sows (Figure 1) measured 2.7 m × 3.2 m and were divided into a resting area (2.7 m × 1.5 m) with concrete floor and an activity area with slatted floor (2.7 m × 1.7 m). A molded piglet box of plastic with an integral plastic flooring measuring 1 m (length) × 0.5 m (width) × 0.45 m (height) was situated in the center of the pen. The box had a single opening of 31 cm × 33 cm facing toward the resting area of the pen and an infrared heating lamp was connected to each box. The day before expected farrowing the piglet box was filled with a 10-cm layer of chopped straw and the heating lamp was turned on. At the back wall of the resting area, a 2.5-m-long farrowing rail of galvanized iron (4 cm in diameter) was positioned 15 cm from the wall and 22 cm above the floor. The back wall and the side walls were made of solid plastic. The front wall that was facing the alley from where the sows were fed and inspected consisted of iron tubes. The feed trough, a water nipple with an open water bowl below, and a straw rack were positioned in the front of the pen. Pens for crated sows (Figure 1) consisted of a total area measuring 2.35 m long and 2 m wide. Two-thirds of the floor was concrete and the remaining third (at the hind part of the sow) had a slatted metal floor. Within a pen the sow was crated by spindle tubing. The crates measured 2 m in length and were adjustable in width from 0.65 to 0.80 cm.

During gestation (from 4 wk after mating) all sows were housed in dynamic groups of 30 to 35 sows with a space allowance of approximately 3 m² per sow and with access to 1 electronic sow feeding station per pen. Primiparous sows and multiparous sows were kept separate in different groups. Pens were divided into a resting area with concrete floor and an activity area with slatted floor also made of concrete. The feeding station was placed in the slatted floor area. Sows received a daily ration of 2.6 kg of feed containing 7.62 MJ of NE/kg. The feeding cycle started at 0500 h and access to the feeding station was closed during nighttime from 2100 to 0500 h. Approximately 200 g of chopped straw per sow was delivered daily by hand in the solid concrete area.

In the farrowing units sows were fed twice daily with a standard sow meal containing 8.40 MJ of NE/kg. Before farrowing sows were fed a ration of 2.6 kg daily; after farrowing, the sows’ feed ration was gradually increased over the next 2 wk until sows were fed ad libitum. Long straw was available ad libitum from a straw rack in the farrowing pens. Crated sows received approximately 500 g of long straw twice daily delivered in front of their feed trough. If soiled, the pen was cleaned once daily, but fresh straw was left untouched. During the previous farrowing and lactation all multiparous sows had been housed in the same type of pen or crate as the experimental housing. Thus, older multiparous sows may have had experience with both types of farrowing housing.
Behavioral Observations and Tests

A digital video camera (TVCCD-14IR, Monacor, Bre- men, Germany) connected to a standard personal computer was placed above each pen/crate. Recordings were carried out from d 114 of pregnancy until 48 h after the birth of first piglet (BFP) using a digital surveillance system (MSH-Video, M. Shafro and Co., Riga, Latvia). The time of birth of each individual piglet was recorded and the mean birth interval as well as the variation (calculated as SD) in the birth intervals within each litter was calculated. Nest-building behavior was observed from 16 h before BFP until 8 h after. The duration of nest building within each hour was recorded (for the applied definition of nest building, see Table 1). The number of postural changes per hour, defined as the number of shifts between the 4 postures (lateral lying, sternal lying, sitting, and standing and walking combined) in Table 1 and the duration of lateral lying per hour were observed from 16 h before and 48 h after BFP. Initial data inspection showed that around 80% of the sows (both crated and penned) did not show extensive nest building earlier than 16 h before BFP. Very little nest building behavior was observed after BFP and therefore only the last 16 h before BFP was included when analyzing the duration of nest building behavior. The 16 h were divided into 2 periods: P1 was 16 to 3 h before BFP and P2 was 2 h before BFP until BFP. After BFP, the 48-h observations of postural changes and lateral lying were divided into 2 periods: P3 was 0 to 8 h after BFP and P4 was 9 to 48 h after BFP.

From BFP until 48 h after, the total number of incidents in which piglets were crushed or at risk of being crushed (defined as a piglet being trapped underneath the sow’s body but surviving, or the piglet being hit and knocked out of the way by the sow during a postural change; Marchant et al., 2001) was observed.

Between 18 and 36 h after BFP, the sow’s response to the playback sound of a screaming piglet was tested (Thodberg et al., 1998). The test was repeated at 4 d after farrowing. The scream of an alien piglet that was held by a person who firmly pressed the body of the piglet was recorded on a tape recorder (AV30 MkII, Dan-Sound Educational, Copenhagen, Denmark) and a standardized 2-min sequence was used during testing. The playback recorder was placed on the roof of the piglet box in the pens and on the bars at the back of the crates. The test was not started until at least 5 min after a nursing bout. The observer remotely switched

Table 1. Ethogram for the behavioral elements observed from 16 h before birth of first piglet (BFP) until 48 h after BFP

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral lying</td>
<td>Sow is lying on the side with one shoulder touching the floor.</td>
</tr>
<tr>
<td>Sternal lying</td>
<td>Sow is lying on the belly without a shoulder touching the floor.</td>
</tr>
<tr>
<td>Sitting</td>
<td>Both feet on the sow’s front legs as well as the sow’s posterior are touching the floor.</td>
</tr>
<tr>
<td>Standing/walking</td>
<td>Sow stands on all 4 legs.</td>
</tr>
<tr>
<td>Nest building</td>
<td>Sow stands on all 4 legs engaged in one of the following behaviors: rooting (repeated snout movements on the floor with or without straw), pawing, carrying straw in the mouth, and arranging straw in the nest (up and down head movements directed toward straw on the ground or in a pile).</td>
</tr>
</tbody>
</table>
on the playback recorder while the sow was lying laterally. Sow behavior was observed from a remote video. The sound of the screaming piglet was played until the sow was standing up or for a maximum of 2 min. The latency until the sow responded either by rolling over to sternal lying, by sitting, or standing up was recorded during the test.

**Other Recordings**

The length of pregnancy was recorded by calculating the number of days from first insemination until the day of BFP. The total number of piglets born was counted and all dead piglets were necropsied to count the number of stillborn piglets and the number of crushed piglets. A piglet was categorized as being stillborn when the piglet had not been breathing, and a piglet was defined as crushed when traumas were visible as internal or external lacerations (for methodology, see Damm et al., 2005b).

**Statistical Analysis**

The following basic GLM was used to analyze data:

Model [1]: $\mu_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \gamma X_{ijk}.$

In model [1], $\mu_{ijk}$ is the expected value of the response variable, $\alpha_i$ is the effect of the $i$th treatment (LC, LP, EP), $\beta_j$ is the effect of the $j$th parity (primiparous sows, multiparous sows), $X_{ijk}$ is the number of total piglets born in the $k$th sow, and $\gamma$ is the corresponding regression coefficient. The experimental unit for treatment and parity effects was sow.

In the analysis of the length of gestation, the average interbirth interval (IBI) as well as the variation in the IBI, the total number of near-crushing situations, the number of postural changes per hour, the time spent in lateral lying per hour, and the duration of nest-building behavior per hour, the response value $Y_{ijk}$ was normally distributed with $N(\mu_{ijk}, \sigma^2)$. Proc Mixed (SAS Inst. Inc., Cary, NC) was used to analyze these data.

For time spent nest building the basic model [1] was extended to include periods (P1 and P2) as a fixed effect and sows as a normally distributed random effect against which the effects of treatment and parity were tested. A similar model was used when analyzing the number of postural changes and time spent in lateral lying, where data from 16 h before BFP until 48 h after BFP was used. In conjunction with P1 and P2, 2 additional periods (P3 and P4) were included in the fixed period effect.

Data on mortality were not normally distributed and were thus analyzed in a GLM for Poisson-distributed data (McCullagh and Nelder, 1989) using Proc Genmod in SAS. Therefore, when analyzing data on mortality (stillborn, crushed, and dead of liveborn), $Y_{ijk}$ was set to logit ($P_{ijk}$), where $P_{ijk}$ is the expected number of dead piglets in the $ijk$th litter. The response value $Y_{ijk}$ was

### Table 2. Progress of farrowing and mortality for primiparous and multiparous sows moved on d 114 of pregnancy (late) to pens (LP) or crate (LC) or moved on d 95 of pregnancy (early) to pens (EP) for farrowing

<table>
<thead>
<tr>
<th>Item</th>
<th>Primiparous sows</th>
<th>Multiparous sows</th>
<th>Primiparous sows</th>
<th>Multiparous sows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LC (n = 9)</td>
<td>EP (n = 10)</td>
<td>LC (n = 10)</td>
<td>EP (n = 10)</td>
</tr>
<tr>
<td>Length of gestation, 1 d</td>
<td>117.5 ± 0.4</td>
<td>117.3 ± 0.4</td>
<td>115.4 ± 0.4</td>
<td>116.8 ± 0.4</td>
</tr>
<tr>
<td>Interbirth interval (IBI), 1 min</td>
<td>29 ± 4.9</td>
<td>27 ± 3.4</td>
<td>27 ± 4.3</td>
<td>29 ± 3.4</td>
</tr>
<tr>
<td>Variation in IBI, 1 min</td>
<td>35 ± 8.3</td>
<td>22 ± 6.1</td>
<td>21 ± 8.0</td>
<td>21 ± 2.3</td>
</tr>
<tr>
<td>Total piglets born</td>
<td>13.4 ± 3.8</td>
<td>13.3 ± 3.6</td>
<td>14.5 ± 2.7</td>
<td>15.8 ± 2.8</td>
</tr>
<tr>
<td>Stillborn, %</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
<td>1.4 (1 to 15)</td>
<td>1.4 (1 to 15)</td>
</tr>
<tr>
<td>Total dead of liveborn, %</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
</tr>
<tr>
<td>Crushed, %</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
<td>1.5 (1 to 15)</td>
</tr>
</tbody>
</table>

a,bRow values within parity with different superscripts differ ($P < 0.05$).

**Note:** Values within parenthesis are mean ± SD because no statistical calculation was carried out.

The estimated mean as a percentage of total born piglets (for total dead and crushed) with the 95% confidence interval shown in parentheses.
assumed binomial distributed with Bin(P_{ijk}, N_{ijk}), where N_{ijk} is the proportion of total piglets born in the ijkth litter. Because of a tendency for overdispersion, the PSCALE option in Proc Genmod in SAS was used.

In analysis of the piglet scream test, it was observed that more than 40% of the sows did not respond to the test. Therefore, data were dichotomized into 2 categories: sows that responded within 2 min and sows that did not. When analyzing the probability that sows were responding to the piglet scream test, the test is shown as least squares means with 95% confidence intervals.

Pairwise comparisons of treatment effects for each parity class were made using the contrast statement in the respective procedures of SAS. Estimated least squares means ± SE are shown in the text, figures, and tables for the normally distributed data, whereas data on mortality and responsiveness to the piglet scream test is shown as least squares means with 95% confidence intervals.

RESULTS

Two primiparous sows on the LP treatment and 1 primiparous sow on the LC treatment were omitted from the analysis because of various technical problems with the video recordings of these animals.

Farrowing

Length of gestation was affected by parity (P = 0.03), with longer gestation length for primiparous sows than for multiparous sows. There was no effect of treatment (P = 0.20) on length of gestation (Table 2).

The mean IBI was affected by an interaction between treatment and parity (P = 0.04). The IBI was not different between EP sows and LP sows in either primiparous (P = 0.83) or multiparous sows (P = 0.35). In contrast, the IBI of primiparous sows was longer in the LC sows than in the LP sows (P = 0.02), whereas there was no difference (P = 0.27) in the IBI between the multiparous LC and LP sows (Table 2). Furthermore, the IBI increased with increasing number of total piglets born (F_{1.50} = 4.7, P = 0.03). There were no differences in IBI between primiparous and multiparous sows in LC sows (P = 0.14), LP sows (P = 0.09), or EP sows (P = 0.40).

A similar interaction between treatment and parity was found for the variation in the IBI (P = 0.01). The variation in the IBI was greater for the primiparous LC sows than for the primiparous LP (P = 0.006), whereas there was no difference (P = 0.18) between multiparous LC sows and multiparous LP sows (Table 2). The primiparous LC sows had a greater variation than multiparous LC sows (P = 0.06), whereas primiparous LP sows had less variation in IBI than multiparous LP sows (P = 0.03; Table 2). Also, the percentage of stillborn piglets was affected by the same interaction (P = 0.003), in that primiparous LC sows had a greater percentage of stillborn piglets than primiparous LP sows (P = 0.004). There was no difference between LC and LP sows (P = 0.26) and between LP and EP sows (P = 0.60) for the multiparous sows. Primiparous LC sows also had greater percentage of stillborn piglets than multiparous LC sows (P < 0.001). The back-transformed estimated mean percentages of stillborn piglets are shown in Table 2 along with the significance level of the chi-square test of the contrasts between the treatments within parity class and between parity class within treatment (Table 2). Using these estimates the odds ratio of giving birth to a stillborn piglet in primiparous LC sows was calculated to be 5 times greater than for primiparous LP sows (95% confidence interval ranged from 1.6 to 14.7; χ^2 = 8, P = 0.004). The odds ratio for primiparous LP sows was not different from that of primiparous EP sows (2.7 with a 95% confidence interval ranging 0.5 to 13.0; P = 0.2). Treatments were not different in the percentage of liveborn piglets that died (P = 0.68) or in the percentage of liveborn piglets that died (P = 0.28; Table 2).

Nesting Behavior and Postural Changes

The time spent nest building tended to be different between treatments (F_{3,53} = 2.6, P = 0.08). However, the EP and LP sows (LP = 101 ± 48 s/h, EP = 142 ± 50 s/h; P = 0.50) were not different and neither were the LP and LC sows (LC = 46 ± 17 s/h, LP = 101 ± 48 s/h; P = 0.13). Time spent nest building was influenced by an interaction between period and parity (P = 0.002) in that primiparous sows and multiparous sows spent an equal amount of time nest building during P1 (primiparous = 221 ± 84 s/h; multiparous = 387 ± 140 s/h), whereas primiparous sows spent less time nest building than multiparous sows during P2 (primiparous = 7 ± 3 s/h, multiparous = 92 ± 33 s/h; P = 0.002).

The number of postural changes was affected by an interaction between period and treatment (P = 0.02). During P1 and P2, respectively, EP sows had fewer postural changes than LP sows (P = 0.04 and P = 0.12), whereas EP sows and LP sows did not differ (P > 0.40) during P3 and P4. There were no differences (P > 0.33) between LP and LC sows in the number of postural changes during any of the periods (Figure 2).

Time spent lying lateral was not affected by treatment (P = 0.68). Time spent lying lateral was influenced by an interaction between period and parity (P = 0.002). Primiparous sows compared with multiparous sows spent more time in lateral lying during P1 (primiparous = 1,138 ± 127 s/h, multiparous = 762 ± 121 s/h; P = 0.03) and P2 (primiparous = 2,601 ± 127 s/h, multiparous = 1,856 ± 121 s/h; P = 0.001), whereas there were no difference in P3 (primiparous = 3,241 ± 127 s/h; multiparous = 3,220 ± 121 s/h) and P4 (primiparous = 2,873 ± 127 s/h; multiparous = 2,658 ± 121 s/h).
Near-Crushing Incidents and Odds Ratio for Responding to the Sound of a Screaming Piglet

The number of near-crushing incidents was affected by parity ($P = 0.03$) and total number of piglets born ($P = 0.03$). Primiparous sows had more near-crushing situations during the 48-h observation period than multiparous sows ($2.25 \pm 1.37$ vs. $0.69 \pm 0.74$), and the number of near crushing situations increased with increasing number of total piglets born (estimated regression coefficient $= 0.11 \pm 0.05$). The number of near-crushing situations tended to differ between treatments ($P = 0.08$), in that LC sows tended to have fewer near-crushing situations than LP ($LC = 0.52 \pm 0.71$, $LP = 1.82 \pm 1.35$; $P = 0.08$). Crushing incidences were not different for LP and EP sows ($LP = 1.82 \pm 1.35$, $EP = 2.04 \pm 1.40$).

The odds ratio for sows to respond to the sound of a screaming piglet did not differ between treatments and between parity on d 1 or 4. On d 1, 59% responded to the scream test, whereas on d 4, 56% responded.

### DISCUSSION

#### Effects During the Nest-Building Phase

Results showed that introducing sows to farrowing pens close to the time of farrowing increased the number of postural changes but had no influence on the time spent nest building. This may indicate that although the motivation to nest build is unaffected by the late move, the sows were still responding to the new environment by general restlessness. Restlessness was not further increased in crated sows introduced late compared with penned sows introduced late. Earlier studies have shown that being crated compared with being penned on introduction to the farrowing unit increases restlessness during the nest-building phase (Jarvis et al., 2001) and induces increased hypothalamic-pituitary-adrenal (HPA)-axis activity (Cronin et al., 1991; Lawrence et al., 1994; Jarvis et al., 1997, 2001). It is thus surprising that we did not find a similar effect of crating in the present study. The effect on restlessness of introducing the sow late to the farrowing unit may be greater than the effect of crating.

Even though crated sows performed a similar number of postural changes they tended to exhibit less nest-building behavior than penned sows moved late. An effect of environment on nesting behavior has been found in several earlier studies (Jarvis et al., 2001; Thodberg et al., 2002; Damm et al., 2003) where sows in farrowing pens spent more time nest building than sows in farrowing crates. In addition, the nature and the amounts of substrate-directed behavior differ between the housing systems (Jarvis et al., 2001). Primiparous sows in the present experiment appeared to start their nest building later than multiparous sows, which has also been found in earlier studies (Jarvis et al., 2001; Thodberg et al., 2002).

#### Effects on the Progress of Farrowing and Stillborn Piglets

Being introduced late to pens did not influence the progress of farrowing and the percentage of stillborn and crushed piglets in either primiparous or multiparous sows. This indicated that the stress of being introduced to a novel environment in itself is not great enough to interfere with the progress of farrowing.

In contrast, crating sows compared with penning them upon late introduction affected both the progress of farrowing and the number of stillborn piglets. The effect was, however, only present in the primiparous sows. Several authors have shown that crating of primiparous sows is stressful and induces changes in the HPA axis during the periparturient period even when the sows were introduced 5 d before expected farrowing (Lawrence et al., 1994; Jarvis et al., 1997, 2001). An additional activation of the HPA axis, increased opioid secretion, or both, caused by the stress of being crated in primiparous sows may contribute to the longer IBI, increased variation in the IBI, and greater percentage of stillborn piglets seen in the present study. Effects of crating primiparous sows on the progress of farrowing and the percentage of stillborn piglets are likely to be the combined effects of the novelty of confinement (Cronin et al., 1991; Lawrence et al., 1994), restriction of the highly motivated nest-building behavior (Lawrence et al., 1994), and farrowing in a novel environment (Lawrence et al., 1992). It seems less likely that being in a crate during farrowing is, in itself, stressful because neither Gilbert et al. (1997) nor Jarvis et al. (1998) found any effect of crating on the HPA-axis activity during farrowing. This is possibly because the sows spent the majority of farrowing lying still. Another explanation may be that the natural physiological increase in cortisol is so great during farrowing that
it overrides any additional stress-induced elevation of cortisol.

The difference between crated primiparous sows and crated multiparous sows in the progress of farrowing and the percentage of stillborn piglets (that were not evident in the penned sows) further strengthens the importance of the novelty of confinement. Primiparous sows were crated for the first time in their lives when introduced to the farrowing crate and may thus have responded more strongly to the stress of crating due to lack of experience with such a restrictive environment. This is supported by Jarvis et al. (2002) and Thodberg et al. (2002) who found that sows in second parity showed some signs of adaptation to crating in response to previous experience, in both nest-building behavior and progress of farrowing.

A change in the housing method from the gestation period to the farrowing period has been shown to affect both the periparturient behavior (Beattie et al., 1995; Harris and Gonyou, 1998; Boyle et al., 2000, 2002) and the percentage of stillborn piglets (Cronin et al., 1996). This supports the concept that the novelty of being crated for the first time in the farrowing unit is stressful to the extent that it affects both behavior and the birth process. The difference in the percentage of stillborn piglets for the primiparous sows moved late to crates compared with the primiparous sows moved late to pens was greater in the present study than was found by Cronin et al. (1996), where primiparous sows were moved earlier to either crates or pens. In addition to the longer lasting negative effect of crating on the birth process (Biensen et al., 1996; Cronin et al., 1996), there may be an additive effect of the novelty of crating.

Because of current European Union legislation, the use of confinement during gestation will be banned beginning in 2014. However, crating is still allowed and widely used during farrowing. In light of the negative effect this shift in housing system has on the progress of farrowing and the percentage of stillborn piglets, as emphasized by both the present and previous studies, it would be beneficial to hasten development of farrowing pens for loose sows.

**Effects on Posture and Maternal Behavior After Birth**

The majority of crushing and death, in general, occur within the first 1 to 2 d of the piglet’s life. During the first 8 h after BFP sows are mainly in lateral lying (Pedersen et al., 2003). Because crushing occurs during postural changes, an increased level of restlessness during this particular period may constitute a potential risk for newborn piglets (Damm et al., 2005a,b). However, late introduction to the farrowing pens did not increase restlessness during this period or during the next 9 to 48 h, indicating that sows were not influenced by the late introduction to an extent that increased restlessness.

The number of postural changes seems important for piglets’ risk of being crushed. In addition, it may be equally important that the sow perform pre-lying behavior that effectively clusters the piglets before the sow lies down. Such behaviors have been shown to reduce the number of near-crushing situations (Marchant et al., 2001). Sows that are disturbed due to the novelty of the environment or restriction in their movement, for example, may be less attentive during lying down and the risk of near-crushing situations may thus be greater. The present study did not, however, find an increased number of near-crushing situations in the sows introduced late compared with the sows introduced early, indicating that sows readily adapted to the new environment. Penned sows tended to have more near-crushing incidents than crated sows, albeit without a parallel increase in percentage of piglets that died from crushing. This may indicate that even though the crate helps reduce the number of near-crushing situations, it may not effectively reduce the risk of crushing. Weber et al. (2007), in a large survey on crated and penned sows, found that a greater percentage of piglets died from crushing in penned sows than in crated sows, whereas total mortality did not differ between the 2 systems. Perhaps weak piglets are more easily crushed in a pen than in a crate because weak piglets are unable to respond properly to pre-lying behavior. On the other hand, weak piglets may die from other causes such as hypothermia, lack of milk, or disease in a crate system. Even though primiparous and multiparous sows had the same number of postural changes after BFP, the primiparous sows had more near-crushing incidents than multiparous sows. An explanation for this could be that primiparous sows are less experienced in performing pre-lying behavior and in clustering the piglets before lying down; however, this has yet to be studied in detail.

Even though large numbers of postural changes and near-crushing situations may be considered a risk to piglet survival, data on crushing do not always support this (Pedersen et al., 2006). How the sow responds when a piglet is trapped underneath it may be equally important. A trapped piglet will scream if possible and it will have a better chance of escaping if the sow responds to its scream by changing posture than if the sow remains lying (Wechsler and Hegglin, 1997). Previous research has shown much variability in the way sows respond to the scream of a trapped piglet (Grandinson et al., 2003). Although the trait seems slightly heritable (Grandinson et al., 2003), environmental disturbances may also affect the response. For example, novelty of the environment may take the sow’s attention away from the newborn piglets or make them more responsive. However, no such effects were found in the present study by the late introduction to pens.

The present study showed that sows introduced late to farrowing pens did not respond to the new environment to an extent that affected progress of farrowing and behaviors of importance for piglet survival. There-
fore, late introduction to the farrowing environment does not seem to be a problem when sows are housed in farrowing pens upon introduction. In contrast, late introduction to crates compared with pens severely affected the progress of farrowing and the percentage of stillborn piglets in primiparous sows. Whether this effect was due to the novelty of crating or the crating itself cannot be verified from the present study because no sows were introduced early to crates.

**LITERATURE CITED**


