Effect of day of mixing gestating sows on measures of reproductive performance and animal welfare

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ABSTRACT: Effects of day of mixing sows after breeding were measured for reproduction and welfare on a commercial research farm. Sows (n = 1,436) were weaned into stalls for breeding, and groups of sows were assigned to 1) no mixing and housed in individual stalls (STL), 2) mixed on d 3 to 7 after breeding (D3), 3) mixed on d 13 to 17 after breeding (D14), or 4) mixed 35 d after breeding (D35). Mixed sows were moved into pens (n = 58 sows/pen) with an electronic sow feeding station and maintained as a static group. In the first 12 d after mixing or movement into STL (period 1), sows were assessed for lameness and lesions every 3 d and then every 2 wk until farrowing (period 2). Cortisol and fights were measured in period 1. Conception rates were reduced (P < 0.005) in D3 (87.1%) and D14 (89.2%) compared to D35 (92.2%) and STL (96.2%). Farrowing rates were lower (P < 0.0001) in D3 (82.8%) compared to D35 (90.5%) and STL (96.2%), but litter size was not (P ≥ 0.20) affected by mixing. The proportion of sows bred within 10 d of weaning was reduced (P < 0.05) for D14 compared to STL, but D3 and D35 did not differ among treatments. Number of fights 24 h after mixing was less (P < 0.0001) for D14 compared to D3 and D35 groups, and serum cortisol was greater (P < 0.05) for D35 compared to STL and D3. From period 1 to 2, lameness increased in D3 and decreased in D35 but did not change for D14 and STL (treatment × period, P < 0.05), whereas leg inflammation did not differ (P > 0.10) among treatments. Head and body lesion scores declined from period 1 to 2 in all mix groups, whereas vulva lesions increased in the D3 and D35 but did not change in D14 and STL (treatment × period, P < 0.0001). These results suggest STL can improve most measures of welfare compared to mixing in groups. However, when mixing sows, assessments for reproductive performance and welfare may change from gestation to farrowing. The poorest reproductive performance and welfare was observed when sows were mixed 3 to 7 d after breeding. There were few differences between the D14 and D35 treatments in reproduction or welfare, but D14—not D35—differed from STL in weaned sows rebred. Overall, results of this trial suggest that, even though any of the mixing days can result in acceptable measures of reproduction, there are clear effects of day of mixing on fertility and welfare, and special attention should be focused on the long-term reproductive and welfare consequences.

Key words: fertility, gestation stall, grouping, reproduction, sow housing, welfare

INTRODUCTION

Public concern about the welfare of sows housed in stalls has resulted in state legislation and numerous food retailers issuing directives to pork producers to limit the use of stalls in the future. This will be a significant change because most sows (USDA, 2010) are currently housed in stalls (National Pork Producers Council, 2012) in large barns (PigCHAMP, 2010; Knox et al., 2013) that facilitate efficient management with high productiv-
Changes in housing systems for sows could impact reproduction and animal welfare. Uniform housing directives could have detrimental consequences for the U.S. pork industry and result in reduced sow welfare and herd reproductive performance. Conflicting evidence exists on the impact of mixing sows in early gestation on pregnancy disruption and increased fetal losses. Reproductive failure has been reported to increase in sows mixed in groups or stressed at weaning (Munsterhjelm et al., 2008) and breeding (Einarsson et al., 2008) and around embryo implantation (Arey and Edwards, 1998). In contrast, no such reproductive failures have been reported for females mixed before estrus (Soede et al., 2007) or in the first 10 or 28 d after service (Bates et al., 2003; Cassar et al., 2008; van Wettere et al., 2008). In addition, research has demonstrated housing in stalls improves the welfare of sows when compared with those mixed in groups (den Hartog et al., 1993). Research suggests that reproductive failures occur more often in early gestation for group-housed sows, whereas problems related to welfare, such as lameness, sometimes appear later in gestation for sows housed in stalls (Karlen et al., 2007). Therefore, the objectives of this study were to determine the effects of day of mixing sows into loose-housing groups of 58 sows/pen after service on reproductive fertility and measures of animal welfare during the summer months on a commercial farm.

MATERIALS AND METHODS

Experimental Design

The use of animals and all experimental procedures were approved by the institutional animal care and use committee of the University of Illinois at Urbana–Champaign. This study was conducted on a 6,000-sow, farrow-to-wean commercial research farm in western Illinois that was newly constructed and operational in summer 2008, with stall housing for the first 30 d of gestation and group housing until farrowing. Sows (n = 1,436) from both PIC C-22 and C-29 genetics (Hendersonville, TN) were of mixed parity (parities 2 to 6) and were assigned randomly in order of estrus expression after weaning to create treatment groups of sows for housing in stalls or group pens. Groups of sows (n = 58) were weaned on Monday through Friday following a 19- to 21-d lactation. At weaning, sows were moved from farrowing to the breeding room where they were placed into individual stalls. Females were checked for estrus once daily in the morning using fenceline exposure to a mature boar with application of the back-pressure test. Once detected in estrus (d = 1), all sows in a replicate were assigned to 1 of the following treatments within 4 d of each other (1.8 ± 0.4 d): 1) not mixed and individually housed in stalls (STL; n = 20 to 40/replicate), 2) mixed between d 3 and 7 after first service (D3; n = 58 to 116/replicate), 3) mixed between d 13 and 17 after first service (D14; n = 58 to 116/replicate), or 4) mixed on or after d 35 after first service (D35; n = 58 to 116/replicate). All parities were represented in each treatment with a range among treatments of 13 to 19, 14 to 16, 16 to 21, 11 to 18, and 28 to 39% for parities 2, 3, 4, 5, and 6, respectively. Sow genetics were also represented across all treatments, with a range of 60 to 67% for C-22 and 33 to 40% for C-29. The study was performed in 6 replicates using batches of weaned sows bred from June through September 2010. A replicate was defined as all treatments sequentially assigned during a 2-wk period.

Sows were inseminated with 3.0 × 10^9 sperm/dose at onset of estrus and at 24-h intervals until no longer standing. Following breeding, sows in STL were moved into gestation stalls and remained in these until farrowing. Following last service, sows assigned to D3 were moved from breeding directly into pens with a single electronic sow feeding station (ESF), whereas D14 and D35 were moved from breeding stalls into gestation stalls until mixed. In the mixed treatments, 58 sows were moved into a group pen within the specified days following first service. The gestation stalls and all ESF pens were located within a single gestation barn. All sows were maintained in their treatment group until approximately d 110 of gestation when they were moved into crates in the farrowing barn.

Housing and Feeding

Sows were housed in a confinement breeding barn that was curtain sided and environmentally regulated by an evaporative cooling system. Supplemental lighting was provided for 10 h each day, with lights on at 0600 h and off at 1600 h. The facility contained 56 pens (5.6 by 17.6 m) located on a fully slatted concrete floor. Each pen contained 1 ESF (Nedap Velos, Gronelo, Netherlands) and 3 water bowls. Sows housed in groups of 58 sows/pens were provided a floor space allowance of approximately 1.74 m²/sow. This facility also maintained 0.6- by 2.1-m stalls used for housing sows during breeding and early gestation. Stalls were located over a fully slatted concrete floor, with each stall supplied with a drop feeder and access to a water trough. Sows were fed conventional diets with nutrients meeting or exceeding requirements (NRC, 1998). Diets fed to sows in gestation contained 30% dried distillers’ grains with solubles (Table 1) and each sow received 2.27 kg/d of feed from weaning until 100 d of gestation, with adjustments given for body condition at 30, 60, and 90 d of gestation. At d 100 of gestation, sows received an additional 0.9 kg/d increase in feed.
### Table 1. Ingredient composition of gestation diet

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>64.325</td>
</tr>
<tr>
<td>Dried distillers grains with solubles</td>
<td>30.000</td>
</tr>
<tr>
<td>Soybean meal, 47.5% CP</td>
<td>2.625</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.425</td>
</tr>
<tr>
<td>Monoacalcium phosphate</td>
<td>0.650</td>
</tr>
<tr>
<td>Salt</td>
<td>0.450</td>
</tr>
<tr>
<td>1-Lys HCL</td>
<td>0.200</td>
</tr>
<tr>
<td>Vitamin/trace mineral/phytase&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.325</td>
</tr>
<tr>
<td>Total</td>
<td>100.000</td>
</tr>
<tr>
<td>Modified ME, kcal/kg</td>
<td>3,220.000</td>
</tr>
</tbody>
</table>

Crude protein: 13.85
Analyzed Ca, %: 0.72
Analyzed P, %: 0.58
Available P, %: 0.43
Sodium, %: 0.24
SID<sup>2</sup> Lys, %: 0.53
SID Me+Cy<sup>3</sup>:Lys: 1.21
SID Thr:Lys: 0.76
SID Trp:Lys: 0.21
SID Val:Lys: 1.03

<sup>1</sup>Premix supplied per kilogram of diet: vitamin A, 9,900 IU; vitamin D<sub>3</sub>, 1,584 IU; vitamin E (d l alpha tocopheryl acetate), 66 IU; vitamin K (menadione activity), 3.96 mg; riboflavin, 8.25 mg; D-pantothenic acid, 29.70 mg; niacin, 39.60 mg; vitamin B<sub>12</sub>, 0.03 mg; D-biotin, 0.25 mg; folic acid, 1.18 mg; pyridoxine, 3.8 mg; chromium propionate, 0.40 mg/kg; Zn (ZnSO<sub>4</sub>), 38.30 mg; Zn (ZnMintrex; Novus International, St. Charles, MO), 49.00 mg; Cu (CuSO<sub>4</sub>), 6.80 mg; Cu (CuMintrex; Novus International), 6.40 mg; Fe (FeSO<sub>4</sub>), 92.30 mg; Mn (MnO), 20 mg; Mn (MnMintrex; Novus International), 19.40 mg; I (ethylenediamine dihydriodide), 0.39 mg; Zn (ZnMintrex; Novus International), 0.15 mg; Se (Na2 Se), 0.15 mg. Phytase was provided as Opptphos (Huvepharma, Sofia, Bulgaria) and was formulated at 750 phytase units/kg of diet.

<sup>2</sup>SID = standardized ileal digestible.
<sup>3</sup>Me+Cy = Methionine + Cysteine.

### Reproductive Measures

Reproductive measures were assessed for all sows in all replicates. Conception rates were determined by transabdominal, real-time ultrasound by the farm technician at 30 ± 2 d after first insemination. Farrowing rate, litter size (total born, born alive, stillbirths, and mummified fetuses), and gestation length were recorded for each sow. Data for experimental sows that farrowed included the proportion of sows that expressed estrus within 10 d following weaning and the interval from weaning to estrus.

### Fighting Events

For sows assigned to the mixing treatments, behavioral data were collected in 4 replicates using 4 to 6 pens/treatment to determine the number of fighting events that occurred within the first 24 h after mixing. Aggressive encounters were not obtained for sows in STL as the criteria used were not applicable. On day of mixing, fighting events between sows were recorded using a fixed-mount digital camcorder (Sony Corp. of America, New York, NY) located above the pen to allow for visualization of the entire pen. Video recording began immediately before mixing and continued for 24 h. Upon video playback, interactions among sows were assessed for aggressive and submissive behaviors based on classifications reported in previous studies (Anil et al., 2006; Seguin et al., 2006; Karlen et al., 2007) with minor modifications. These behavioral classifications included 1) sows facing each other, 2) side-by-side alignment, and 3) heads up with biting and body movement. Biting targets included face, ear, neck, body, and rump. Aggressive encounters were considered terminated when 1 sow retreated. Interference from another pig was considered an additional fighting event, and pushes (given with head or shoulder) were also considered agonistic behaviors. The determination for the numerical measure for number of fights in each pen during a 24-h recording period required adjustment in some cases because the usable recording period ranged between 18 and 24 h for individual pens.

### Lesions, Leg Assessment, and Body Condition Score

Sows from all treatments were observed in 6 replicates for lesions and BCS on d 3, 6, 9, and 12 after mixing or movement into STL and then every 2 wk thereafter until farrowing. Lesion score assessments included the head (and neck), body (including the shoulder, back, side, rear, and udder), leg, and vulva. Each sow was assessed for the presence or absence of new or old lesions along with the severity of the wound based on a modification of the classification used by Salak-Johnson et al. (2007). Lesion scores were classified as none (0 = no lesions), low (1 = few lesions; moderate wounds displaying scabbing over scratch), moderate (2 = numerous wounds; scratch showing red color), or high (3 = abundant lesions; bleeding evident on wounds). Vulva lesions were categorized as none (0 = no lesions), moderate (1 = scabbing or abrasion; red in color), or high (2 = laceration and bleeding). Leg assessment included lameness and leg inflammation, and scores were defined as either yes (1) or no (0) with sows observed or not observed with lameness or leg inflammation. Leg assessment was assigned once the sow in the stall was standing, whereas sows in pens were evaluated if they were standing or were induced to stand and began to walk. Body condition scores were assessed using the visual-appraisal method (posterior assessment of sow) described by Coffey et al. (1999), from 1 (lowest) to 5 (greatest). The same individual recorded all scores.

### Blood Collection and Hormone Assay

Blood samples were obtained in 3 replicates with baseline samples for cortisol collected from a random se-
lection of sows from each treatment but before movement into STL or mixing pen \((n = 20 / \text{treatment})\). Subsequent blood samples were obtained 3 and 9 d after movement into STL or mixing pens. Blood was collected within each treatment from sows classified by lesion scores as low \((n = 5)\), moderate \((n = 5)\), and high \((n = 5)\). Because it was not possible to determine which sows would be classified by lesion score or bleed all weaned sows, the mean of the baseline samples within each treatment was used for the determination of a fold-change in cortisol. Blood samples \((4 \text{mL})\) were collected via jugular venipuncture into Vacutainer tubes \((\text{Becton, Dickinson and Co., Franklin Lakes, NJ})\) following restraint of sows using a nose snare. Sampling occurred between 0900 and 1100 h, with blood obtained within 2 min of snaring. Samples were kept at room temperature for 1 h and then placed at refrigeration temperature for 12 h before centrifugation at \(400 \times g\) for 15 min at \(4^\circ\text{C}\). Serum was aspirated and transferred into polypropylene tubes for storage at \(-20^\circ\text{C}\) until assay.

Cortisol was measured in serum using a commercial RIA kit \((\text{C}o\text{a}t-\text{A}-\text{C}ount; \text{Siemens, Los Angeles, CA})\) that has been validated for use in swine \((\text{Tast et al., 2002; Collier et al., 2011})\). Assays were performed according to manufacturer instructions with modification for use of 12.5, 25, or 50 \(\mu\text{L}\) of serum depending on whether cortisol values were above or below the limits of the kit standard curve. Samples that were still too low after use of 50 \(\mu\text{L}\) of serum were reported as nondetectable. The intra- and interassay CV were 7.3 and 6.5%, respectively, with a minimal detectable cortisol concentration of 2 ng/mL. Mean baseline measures for cortisol \((\text{ng/mL})\) were 26.2 ± 1.8, 22.9 ± 2.2, 15.6 ± 2.3, and 21.9 ± 2.1 for STL, D3, D14, and D35, respectively.

**Statistical Analysis**

Sow data were collected and recorded using Agrisoft Ltd. software \((\text{Suffolk, UK})\) and subsequently exported into a spreadsheet. Data were subjected to ANOVA with continuous response measures analyzed using the PROC MIXED procedure and binary response variables analyzed using PROC GLIMMIX of SAS \((\text{SAS Inst. Inc., Cary, NC})\) for significance \((P \leq 0.05)\) of the main effects of treatment using the \(F\)-test. Differences between least squares means were identified using the Tukey-Kramer adjustment for multiple means comparisons using pairwise \(t\) tests. Binary data analyses for conception and farrowing rates, sows rebred within 10 d, and proportion of sows lame or with leg inflammation were performed using a binary distribution using a logit-link function. Least squares means were then transformed back to the observed scale for interpretation. For count data \((\text{fights})\) and proportional data \((\text{cortisol})\), analyses were performed using a Poisson distribution and a log-link function with least squares means transformed back to the observed scale. Models for the reproductive responses included the main effects of treatment and random effects of replicate with genetics and parity included as covariates. Other variables, such as lactation length and services/sow, were included as covariates and removed if not significant. For welfare measures, models included the main effects of treatment, period, and their interaction, with replicate included as a random effect and genetics and parity as covariates. Welfare measures were analyzed by period 1 \((\text{observations obtained during the first 12 d after mixing or movement into STL})\) or period 2 \((\text{observations made subsequent to d 12 until d 110 of gestation})\). Cortisol was analyzed as a proportional change from the pretreatment baseline mean for the sows in each treatment. The assumptions of the ANOVA for a normal distribution of data were tested using PROC UNIVARIATE and Levene’s test was used to test the homogeneity of variance. Data that could not meet the assumptions were transformed for analysis.

**RESULTS**

**Reproductive Measures**

Conception rate was reduced \((P < 0.05)\) in sows in the D3 compared to those in the D35 and STL, whereas D14 did not differ \((\text{Table 2})\). Farrowing rate was also reduced \((P < 0.0001)\) for sows in the D3 group compared to sows in all other treatment groups. Total number of piglets born \((12.2 ± 0.1)\), born alive \((11.5 ± 0.1)\), and stillborn \((0.60 ± 0.03)\) and mummified fetuses \((0.08 ± 0.11)\) did not differ \((P ≥ 0.20)\) among treatments. After weaning, fewer sows \((P < 0.05)\) in the D14 treatment expressed estrus and were mated within 10 d of weaning compared STL, whereas D3 and D35 were similar among treatments. However, the interval from weaning to estrus \((4.3 ± 0.05 \text{d})\), gestation length \((115.8 ± 0.1 \text{d})\), lactation length \((22.1 ± 0.1 \text{d})\), and number of inseminations \((1.98 ± 0.01)\) were similar \((P ≥ 0.23)\) among treatments.

**Fighting Events and Cortisol Concentrations**

Sows in the D14 treatment had 33% fewer \((P < 0.0001)\) fighting events than sows in the D3 or D35 treatments \((\text{Fig. 1})\). Sows mixed 35 d after breeding had a greater \((P < 0.05)\) increase in serum cortisol concentrations from baseline during period 1 compared to sows in STL and D3, whereas D14 was similar among treatments \((\text{Fig. 2})\).

**Incidence of Lameness and Leg Inflammation, Lesion Scores, and Body Condition Score**

Incidence of lameness increased from period 1 to 2 for sows in the D3 group, whereas sows in D35 had the greatest percentage of lameness during period 1 but lameness decreased in these sows during period 2; however, the
incidence of lameness was similar in STL and D14 sows between observations periods (treatment × period, \( P < 0.0001 \); Fig. 3). Sows in the D3 group exhibited a greater incidence of leg inflammation from period 1 to 2, whereas leg inflammation scores decreased in sows from the D35 treatment between periods 1 and 2 (treatment × period, \( P < 0.05 \); Fig. 4). Conversely, leg inflammation did not change between observation periods for sows in STL and those in the D14 treatment. Regardless of when sows were mixed after breeding, mixed sows received greater head and body lesion scores than sows in STL during periods 1 and 2. However, head lesion scores decreased in the mix treatments and did not change in STL whereas body lesion score decreased in the mix treatments but increased in STL from period 1 to 2 (treatment × period, \( P < 0.05 \); Fig. 4). Conversely, leg inflammation did not change between observation periods for sows in STL and those in the D14 treatment. Regardless of when sows were mixed after breeding, mixed sows received greater head and body lesion scores than sows in STL during periods 1 and 2. However, head lesion scores decreased in the mix treatments and did not change in STL whereas body lesion score decreased in the mix treatments but increased in STL from period 1 to 2 (treatment × period, \( P < 0.05 \); Fig. 5 and 6, respectively). In addition, sows in D3 and D35 groups received greater vulva lesion scores in period 2 than period 1, whereas vulva lesion scores did not change in sows in the STL and D14 treatment groups between observation periods (treatment × period, \( P < 0.0001 \); Fig. 7). Finally, BCS increased for sows in STL, D3, and D14 groups from period 1 to 2, but BCS were similar between the observation periods for sows in the D35 group (treatment × period, \( P < 0.0001 \); Fig. 8).

**DISCUSSION**

Results of this experiment demonstrated that both reproduction and measures of sow welfare can be affected by week of mixing after breeding even in a well-managed group-housing system. Mixing sows into groups on certain weeks postbreeding resulted in differential responses in fighting, lesion scores, and cortisol soon after mixing, regardless of the specific week that mixing occurred. However, long-term consequences were evident as a result

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**Table 2. Comparison among sows bred and maintained in individual gestation stalls (STL) or mixed into group housing (58 sows/group) at 3 to 7 d (D3), 13 to 17 d (D14), and 35 d (D35) after breeding on reproductive performance**

<table>
<thead>
<tr>
<th></th>
<th>STL</th>
<th>D3</th>
<th>D14</th>
<th>D35</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicates</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Sows</td>
<td>158</td>
<td>463</td>
<td>347</td>
<td>464</td>
<td></td>
</tr>
<tr>
<td>Parity</td>
<td>4.4 ± 0.1</td>
<td>4.6 ± 0.1</td>
<td>4.3 ± 0.1</td>
<td>4.2 ± 0.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>Lactation length, d</td>
<td>21.5 ± 0.3</td>
<td>22.0 ± 0.2</td>
<td>21.8 ± 0.2</td>
<td>21.8 ± 0.2</td>
<td>0.48</td>
</tr>
<tr>
<td>Number of services/sow</td>
<td>1.96 ± 0.01</td>
<td>1.96 ± 0.01</td>
<td>1.97 ± 0.01</td>
<td>1.97 ± 0.02</td>
<td>0.96</td>
</tr>
<tr>
<td>Conception rate, %</td>
<td>96.2 ± 4.2(^a)</td>
<td>87.1 ± 1.4(^b)</td>
<td>89.2 ± 1.7(^a)</td>
<td>92.2 ± 1.8(^a)</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Farrowing rate, %</td>
<td>92.8 ± 3.1(^a)</td>
<td>82.8 ± 1.3(^b)</td>
<td>87.8 ± 1.6(^ab)</td>
<td>90.5 ± 1.6(^a)</td>
<td>0.001</td>
</tr>
<tr>
<td>Gestation length</td>
<td>115.9 ± 0.1</td>
<td>115.8 ± 0.1</td>
<td>115.9 ± 0.1</td>
<td>115.9 ± 0.1</td>
<td>0.36</td>
</tr>
<tr>
<td>Total born/litter</td>
<td>12.4 ± 0.3</td>
<td>11.9 ± 0.2</td>
<td>12.4 ± 0.2</td>
<td>12.2 ± 0.2</td>
<td>0.24</td>
</tr>
<tr>
<td>Pigs born alive/litter</td>
<td>11.8 ± 0.3</td>
<td>11.3 ± 0.2</td>
<td>11.6 ± 0.2</td>
<td>11.5 ± 0.2</td>
<td>0.47</td>
</tr>
<tr>
<td>Stillborn pigs/litter</td>
<td>0.59 ± 0.08</td>
<td>0.53 ± 0.05</td>
<td>0.65 ± 0.06</td>
<td>0.63 ± 0.05</td>
<td>0.31</td>
</tr>
<tr>
<td>Mummified fetuses/litter</td>
<td>0.06 ± 0.03</td>
<td>0.08 ± 0.02</td>
<td>0.07 ± 0.02</td>
<td>0.04 ± 0.02</td>
<td>0.50</td>
</tr>
<tr>
<td>Sows rebred within 10 d, %</td>
<td>96.6 ± 5.1(^a)</td>
<td>90.4 ± 2.3(^ab)</td>
<td>88.8 ± 2.1(^b)</td>
<td>93.0 ± 2.2(^ab)</td>
<td>0.04</td>
</tr>
<tr>
<td>Wean to estrus interval for sows rebred within 10 d, d</td>
<td>4.5 ± 0.1</td>
<td>4.3 ± 0.1</td>
<td>4.2 ± 0.1</td>
<td>4.4 ± 0.1</td>
<td>0.34</td>
</tr>
</tbody>
</table>

\(^a\)–\(^d\) Within a row, least squares means (±SE) lacking common superscript letters differ (\( P < 0.05 \)).

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**Figure 1.** The effect of mixing and housing treatments (D3 = mixed 3 to 7 d after breeding and group housed, D14 = mixed 13 to 17 d after breeding and group housed, and D35 = mixed 35 d after breeding and group housed) on the number of fighting events observed in the 24 h following mixing into groups (\( P < 0.0005 \)). \(^a\)\(^b\) Bars lacking a common letter differ, \( P < 0.05 \).

**Figure 2.** The effect of mixing and housing treatments (STL = not mixed and maintained in individual stalls, D3 = mixed 3 to 7 d after breeding and group housed, D14 = mixed 13 to 17 d after breeding and group housed, and D35 = mixed 35 d after breeding and group housed) on serum cortisol concentrations relative to pretreatment baseline values (\( P < 0.0005 \)). \(^a\)\(^b\) Bars lacking a common letter differ, \( P < 0.05 \).
of day of mixing in the form of farrowing and rebreeding failures, lameness, leg inflammation, and lesions. Despite the fact that reproductive and measures of sow welfare were affected by day of mixing, all treatment measures for reproduction met or exceeded current industry averages for farrowing rate, litter size, and sows bred within 7 d of weaning (PigCHAMP, 2010). For reproduction, this is even more notable because the study was conducted in the summer months when increased reproductive failures are frequently reported (Love et al., 1993; Xue et al., 1994; Koketsu et al., 1997). The National Pork Board (2012) has published some assessments for sow welfare with acceptable limits for sow BCS and has suggested observations for lameness and lesions could be helpful for benchmarking. In this experiment, measures for welfare were influenced by treatment and the observation period of the study.

Reproductive performance is a key measure for profitability for swine farms (Britt, 1986), and reproductive failure is a leading reason for culling (Koketsu et al., 1997; USDA-APHIS, 2006) and reduced longevity (Koketsu et al., 1999). The causes of reproductive failure are often unknown but have been associated with certain types of stressors, including seasonality and disease (Tubbs, 1997; Britt et al., 1999). Even though there is no consensus on when mixing sows should occur after breeding to avoid reproductive failure, most recommendations state sows should not be mixed until after the time of embryo implantation (Von Borell et al., 2007; Schwartz, 2011), which occurs from d 13 to 25 (Johnson et al., 2009). Results of the
current study do not support this because conception rates and farrowing rates were only reduced in sows that were mixed on D3 after mating when compared to sows mixed after D35 or those not mixed and maintained in stalls. It is also important to note that there was no reduction in farrowing rate for D14 and D35 treatments compared to sows not mixed and housed in stalls throughout gestation. An explanation for why stress could disrupt pregnancy could come from the work of Lang et al. (2004), who mimicked the stress response by injecting sows with corticosterone-releasing hormone or ACTH and observed a reduction in prostaglandin metabolite, suggesting a possible effect on uterine or corpora lutea function, which could alter pregnancy establishment. Arey and Edwards (1998) reviewed the effects of mixing sows in the first 10 d after breeding and noted that pregnancy rates were reduced in most studies, whereas litter size was reduced in only a few studies, when compared to mixing sows on d 11 to 31 following mating. In their review, Arey and Edwards (1998) attributed pregnancy failure and litter size reductions to increased aggression and elevated circulating cortisol concentrations. Moreover, stress (as measured by corticosteroid levels) increased in group-housed gilts with restricted floor space, which was associated with a reduction in the expression of estrus (Hemsworth et al., 1986). In comparison to individual housing, group housing was reported to reduce conception rates and result in greater sow culling, especially in the seasons most associated with infertility (Hurtgen and Leman, 1980). Munsterhjelm et al. (2008) reported that disruption of pregnancy was more likely to occur among group-housed sows than sows in stalls, and Estienne et al. (2006) reported that mixing groups of gilts immediately after AI increased skin lesion scores and reduced pregnancy rates. Collectively, these studies would support the present observations that mixing sows in the first week after mating caused the greatest pregnancy failure, which was also associated with reduced welfare from the stress of aggression. den Hartog et al. (1993) and Kranendonk et al. (2007) have attributed reduced fertility in group-housed sows to problems associated with feed intake and BW gain during gestation when compared to individually housed sows in stalls. Kranendonk et al. (2007) suggested that competition associated with social rank in group-housed sows using electronic sow feeders can result in feed intake problems and BW gain. Even though sow BW was not recorded in the present experiment, there were subtle differences in BCS and, more importantly, there were overt differences in fighting events and lesions among mixing treatments, which might have led to disrupted feed intake and pregnancy failure. Einarsson et al. (2008) indicated that the stress associated with feed competition and aggression can negatively affect the sow by diverting energy resources away from certain biological functions, including immune function, growth, metabolism and reproduction. Results for the sows mixed between d 3 and 7 after breeding suggest reproductive failure might also be associated with their lower BCS soon after mixing and even into later gestation compared to the other treatments. This lower BCS could have resulted from interrupted feed intake as well as a diversion of energy away from reproduction to deal with aggression for establishing social order, increased stress of movement in the case of lameness, and the need to cope with the pain and healing of lesions.

In contrast to the observations in the present experiment, there are several studies that report no effect of housing or mixing stress on measures of reproduction. Even though Bates et al. (2003) reported improved reproduction in sows that were housed in group pens compared to individual pens, and competition associated with social rank in group-housed sows using electronic sow feeders can result in feed intake problems and BW gain. Even though sow BW was not recorded in the present experiment, there were subtle differences in BCS and, more importantly, there were overt differences in fighting events and lesions among mixing treatments, which might have led to disrupted feed intake and pregnancy failure. Einarsson et al. (2008) indicated that the stress associated with feed competition and aggression can negatively affect the sow by diverting energy resources away from certain biological functions, including immune function, growth, metabolism and reproduction. Results for the sows mixed between d 3 and 7 after breeding suggest reproductive failure might also be associated with their lower BCS soon after mixing and even into later gestation compared to the other treatments. This lower BCS could have resulted from interrupted feed intake as well as a diversion of energy away from reproduction to deal with aggression for establishing social order, increased stress of movement in the case of lameness, and the need to cope with the pain and healing of lesions.

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to sows individually housed, many studies indicate no
effect on reproductive performance. Harris et al. (2006)
reported no change in sow fertility despite greater lesion
scores and incidence of lameness for sows in groups com-
pared with those maintained in stalls. Furthermore, van
Wettere et al. (2008), Soede et al. (2007), and Cassar et al.
(2008) all observed that mixing sows or gilts into groups
at various days after breeding had no effect on pregnancy
rate or litter size, even though fighting events were in-
creased by mixing. Salak-Johnson et al. (2007) also re-
ported no difference in reproductive performance among
sows mixed into groups approximately 30 d postbreed-
ing that were provided different floor space allowances,
despite differences in sow BW, BCS, lesion scores, and
aggressive encounters. In comparing group formation in
dynamic vs. static systems with 30 sows/group and us-
ing an ESF, Anil et al. (2006) failed to observe an effect
on reproduction compared to sows in stalls, even though
total injury score and aggression were increased in the dy-
namic system. And although scientific studies were not
performed, recent industry reports also suggest that re-
productive performance in several group-housing systems in
North America can work well when mixing sows either in
the first week or after about 35 d (Parsons, 2011), whereas
mixing at implantation is not practiced due to concerns
about increased reproductive failures.

Although results of the current study concur with
those of others, especially for sows in the D35 treatment
and to a greater extent those in the D14 group, fewer
sows in the D14 treatment were rebred after weaning
compared to unmixed sows maintained in gestation
stalls. Contrary to industry recommendations, but simi-
lar to many scientific studies, a reduction in farrow-
ing rate or litter size was not observed in the present
study when mixing at time of implantation. However,
in contrast to some of the scientific studies and industry
recommendations, current results indicated that sows
mixed in the first week after mating had reduced con-
ception and farrowing rates compared to sows mixed
35 d after breeding and those not mixed and maintained
in stalls. Karlen et al. (2007) also compared sows in
stalls to those that were grouped in the first week after
service and observed mixed sows had lower farrowing
rates, more lesions, and increased salivary cortisol after
grouping. Interestingly, sows housed in stalls exhibited
a slight increase in lameness in late gestation and al-
tered immune function (Karlen et al., 2007), suggesting
that extended stall housing itself may be associated with
stress. The discrepancy for why some research studies
report reproductive failure and others do not as a result
of group housing or day of mixing could be influenced
by several variables, including different genetics, par-
ties, season, day of mixing, group size, floor space, pen
design, group integrity, and feeding system, to name a
few. When comparing gestation stall farms to group-
housing farms that used postimplantation mixing within
a single production system, Schwartz (2011) reported
that reproductive performance was similar between
sows in group-housed and individual stall systems,
even though reproductive performance was numerically
greater for the individual gestation stall farms. The in-
dustry reports, such as Schwartz (2011), are valuable as
they provide support for the application of results from
controlled experiments; however, industry reports are
designed to detect obvious differences in fertility in re-
response to grouping sows and are limited scientifically
as they do not include measures of welfare and cannot
control confounding factors between different farms. It
would appear that controlled comparisons within or be-
tween similar farms will be required to help producers
determine the optimal mixing strategy for detecting true
differences in reproductive performance and welfare.

Although the majority of reports involving day of
mixing sows have focused on pregnancy and farrowing
failures, it is important to acknowledge that in the pres-
ent study, there was no effect of mixing day on litter size.
If losses were to occur, it could manifest itself in fertil-
ization failure, excessive embryo loss before or after ma-
ternal recognition of pregnancy, and failure to establish
pregnancy. Collectively, these problems could all appear
as sows diagnosed as pregnant or open using ultrasound at
approximately 30 d after mating or, if estrus was observed,
would appear as regular or irregular returns. In the pres-
ent study, all treatments showed a decline from conception
rate to farrowing rate but with 4% of pregnancies lost after
d 30 for the D3 and STL treatments and only 1% losses
in the D14 and D35 groups. However, this did not result
in a measurable effect on litter size. More importantly, as
an indicator of longevity, the D14 group demonstrated a
lower proportion of sows that expressed estrus within 10
d of weaning when compared to sows maintained in stalls
but did not differ from those mixed 3 to 7 or 35 d after
breeding. Sow longevity has received much attention as
it has implications for both profitability and sow welfare.
Reproductive failure is often listed as the primary or sec-
ondary reason for sow culling, with conception failure and
failure to express estrus as the leading causes for removal
(Koketsu et al., 1997; Tubbs, 1997; Heinonen et al., 1998).
Fewer sows expressing estrus after weaning would be an
important indicator for longevity (Koketsu et al., 1999).
Even though longevity was not measured in this study, it is
likely that a lower percentage of sows in the D3 treatment
would remain in the herd until the third parity based on the
observed reduction in farrowing rate and increased levels of
aggression, lesions, and lameness.

Important differences in welfare were affected by treat-
ment and observation period. Fighting events were 33%
greater in the 24 h following mixing for the D3 and D35
groups compared to the D14 group. It is unclear why there were fewer fighting events among sows in the D14 treatment when compared with the other treatments because the assessed welfare measures were often intermediate between the other mixing treatments. Fighting is reported to result from behaviors associated with establishing social hierarchy and can be affected by feeding system, sow size, previous exposure to other group members, size of the group, and pen design, to name a few. As an indicator of stress, cortisol increased in period 1 for all sows relative to baseline, and compared to unmixed sows maintained in gestation stalls, the greatest increase was observed for D35 sows but did not differ for sows in the D3 and D14 groups. Some studies have shown increased cortisol following mixing (Hemsworth et al., 1986; Jansen et al., 2007; Karlen et al., 2007), whereas others report no increase (Anil et al., 2006; Soede et al., 2006) or an increase in individually stalled females compared to those in groups (Estienne et al., 2006; Karlen et al., 2007). The contradictory results for cortisol could be related to factors such as the timing and frequency of sampling relative to the stress and confounded by elevations in cortisol in sows housed in stalls as a result of stress from limitations in social interaction and movement (Von Borell et al., 2007). However, blood sampling for cortisol in period 1 could not be used to address the long-term effects of chronic stress in period 2. Two clear indicators of reduced welfare were observations of lameness and lesions, which increased in all mixed sows compared to those sows maintained in stalls in both observation periods. However, without reference to specific days or periods, previous reports have indicated that gilt, or sows, mixed after mating exhibited greater fighting, lesions, scratches, and cortisol concentrations than those maintained in stalls (Estienne et al., 2006; Jansen et al., 2007; Karlen et al., 2007). In the present study, important treatment × period interactions were noted for lameness, leg inflammation, and lesions, but each of these measures was independent of the other. Lameness and leg inflammation increased between periods 1 and 2 in D3 sows but decreased between observation periods in D35 sows. Even though head, body, and vulva lesions were increased in mixed sows in period 1, head and body lesions declined in period 2 among mixed sows, although vulva lesions actually increased in the D3 and D35 treatments in period 2. Overall, it appears that the measure of welfare, the period of observation, and the day of mixing can all be factored into the decision-making process for sow management and assessment of sow well-being.

Results of this study indicated that day of mixing can impact both reproductive performance and measures of welfare. Compared to mixing sows 35 d after breeding and those individually housed in stalls throughout gestation, mixing sows in the first week after service (D3) reduced conception rates and farrowing rates but had no effect on litter size. This reproductive failure was also associated with the poorest overall animal welfare compared to the other treatments as measured by lameness, lesion, and BCS. Mixing sows in the third week (D14) at the start of implantation had no effect on conception rate, farrowing rate, or litter size but did reduce the percentage of sows rebred after weaning. The sows in the D14 treatment had intermediate overall welfare, with some measures greater or lesser than those mixed 35 d after breeding. The reproductive performance of sows mixed after 35 d after breeding (D35) was most similar to that of sows housed in stalls throughout gestation. Some measures of welfare for sows mixed after d 35 was improved compared to mixing earlier, but others were not and depended on when and what welfare measure was assessed after mixing. Management of sows in stalls resulted in the best overall reproductive performance, with the most measures of welfare greater than any of the mixed treatments. It is important to note that in this study, the D14, D35 and STL treatments showed farrowing rates of 88, 91, and 93%, respectively, with other measures, such as rebreeding after weaning, also exceeding performance expectations for sows bred in summer and fall. However, when comparing these same treatments for welfare, measures of lameness increased notably with mixing as did some measures of lesions. Future efforts to improve the reproductive performance and welfare of the sows for group housing should consider strategic use of individual gestation stalls to minimize the negative effects of mixing in early and perhaps even late gestation.

LITERATURE CITED


