RESEARCH REPORT

ANIMAL WELFARE

Title: Effect of Day Mixing Gestating Sows on Measures of Reproduction and Animal Well-Being – **NPB #09-030** revised

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Industry Summary

Legislation and company directives to end the use of the gestation stall for reasons involving sow welfare are in effect. There is conflicting evidence regarding the effects of sows maintained in stalls or when mixed into groups on reproductive performance and animal welfare. From the industry perspective, the housing of sows in stalls lowers the public's perception of the welfare status of sows in the care of producers. From a producer perspective, mixing is problematic because it can cause pregnancy losses, reduced litter size, and loss of animals from fighting. This study was performed to evaluate the effects of day of mixing sows into groups during gestation on reproductive measures and measures of sow welfare. The treatments were applied in replicates during the summer months to obtain greater sensitivity to stress. The study was performed on a large 6000 sow commercial research farm in the Midwest. Sows of mixed parity (2 to 6) were weaned and checked for estrus. Upon detection of estrus, sows were assigned to treatment and bred by AI. Sows (n=1436) were assigned to housing treatment in: 1) stalls from weaning through gestation (Stall); 2) stalls from weaning until mixing at d 3-7 (D3 Mix); 3) stalls from weaning until mixing at d 13-17 (D14 Mix); and 4) stalls from weaning until mixing after d 35 (D35 Mix). All mixed sows were mixed into pens in a group of 58 sows. Each pen provided adequate floor space and each had one electronic sow feeding station. The Stall and the D35 Mix each served as controls to test for the effect of early mixing before pregnancy establishment at D3 Mix and later at time of implantation at the D 14 Mix. We recorded reproductive measures as pregnancy rate at day 30, farrowing rate, litter size, and for longevity as the proportion of sows that farrowed that remained in the herd to be bred within 10 days of weaning. Measures of well-being were also obtained and included early measures (Period 1) and later measures (Period 2). In Period 1, we recorded fighting events, lesions, and lameness, cortisol change, and body condition in the first 12 d after mixing or their movement into their permanent stall. In period 2, we recorded lesions, lameness and body condition from d 13 until farrowing. From a reproductive standpoint, conception rates were lower with the early D3 (87.1%) and D14 Mix (89.2%) treatments compared to the later D35 Mix (92.2%) and the Stall (96.2%) treatments. Farrowing rates remained lower in the D3 Mix (82.8%) compared to other treatments but the D14 Mix (87.8%) did not differ from the D35 Mix (90.5%) and the sows housed in Stall (92.8%). Litter size was not affected by any treatment (P > 0.10) and averaged 12.0 total born pigs. For sows that farrowed, there was an effect of treatment on the proportion of sows that were bred within 10 d of weaning. Fewer sows were bred (P < 0.05) for sows in the D3 and D14 Mix treatments compared to those in Stalls but the D35 Mix did not differ from either. The number of fights in the first 24 h after mixing was lower in the D14 Mix compared to the D3 and D35 Mix groups (P <0.0001) and did not occur in Stall. In period 1, cortisol was measured as the stress hormone, and cortisol increases were greatest (P< 0.05) in sows that were mixed compared to sows housed in the Stall. There were also (P < 0.05) effects of treatment, period and interactions for lameness, leg inflammation and lesions. In periods 1 and 2, mixing resulted in increased incidence of lameness, and increased lesion scores compared to those sows maintained in the Stall. Incidence of leg inflammation was not different in period 1 but was increased in period 2 for D3 Mix and Stall compared to other treatments (P < 0.05). A ranking from best to worst was performed using all measures for reproduction and well-being measures in each period. Final ranking order was the same for all measures and periods with the best ranking order: 1) Stall; 2) D35 Mix; 3) D14 Mix, and 4) D3 Mix. These results suggest that optimal reproduction and well-being can be achieved with use of stalls and that day of mixing can reduce all measures. Mixing in the first week results in reduced farrowing and well-being measures compared to mixing after the fifth week while mixing after the 2nd week shows intermediate effects. When mixing sows, short term responses for well-being and long term measures for reproduction and well-being must be considered to evaluate the effects of housing management. It would appear that strategic use of the use of the stall could be helpful for improving sow reproduction and welfare. Overall however, when examining the endpoint measures of reproduction and taking into consideration the classification of average well-being scores, our data suggests that in well-managed farms problems associated with day of mixing could have minimal impact.

Keywords:
Gestation, Group housing, Mixing, Reproduction, Sow, Sow housing, Stall, Welfare

Scientific Abstract:

This study tested for the effects of day of mixing sows following breeding on reproduction and well-being during the summer months on a commercial farm. Sows (n = 1436) of mixed parity (2 - 6) were weaned and assigned at estrus to housing treatment in: 1) stalls from weaning through gestation (Stall); 2) stalls from weaning until mixing at d 3-7 (D3 Mix); 3) stalls from weaning until mixing at d 13-17 (D14 Mix); and 4) stalls from weaning until mixing after d 35 (D35 Mix). Sows were mixed into pens in a group of 58 sows. Measures of well-being were obtained to include fighting events, lesions, and lameness, cortisol change, and body condition in the first 12 d after mixing or movement into a permanent stall (Period 1) and lesions, lameness and body condition thereafter until farrowing (Period 2). Conception rates were lower with D3 (87.1%) and D14 Mix (89.2%) compared to D35 Mix (92.2%) and Stall (96.2%). Farrowing rates remained lower in D3 Mix (82.8%) compared to other treatments but D14 Mix (87.8%) did not differ from D35 Mix (90.5%) and Stall (92.8%). Litter size was not affected by treatment (P > 0.10) and averaged 12.0 total born pigs. For sows that farrowed, there was an effect of treatment on the proportion of sows bred within 10 d of weaning which was lower (P < 0.05) for sows in the D3 and D14 Mix treatments compared to those in Stalls but not the D35 Mix. Number of fights in the first 24 h after mixing was lower in the D14 Mix compared to the D3 and D35 Mix groups (P <0.0001). In period 1, cortisol increases were greatest (P< 0.05) in mixed sows compared to sows in Stall. There were (P < 0.05) effects of treatment, period and interactions for lameness, leg inflammation, lesions and body condition score. In periods 1 and 2, mixing resulted in increased incidence of lameness, and increased lesion scores compared to Stall. Incidence of leg inflammation was not different in period 1 but was increased in period 2 for D3 Mix and Stall compared to other treatments (P < 0.05). A ranking from best to worst was

performed using all measures for reproduction, and well-being measures in each period. Final ranking order was the same for all measures and periods with the best ranking order: 1) Stall; 2) D35 Mix; 3) D14 Mix, and 4) D3 Mix. These results suggest that optimal reproduction and well-being can be achieved with use of stalls and that day of mixing can reduce all measures. Mixing in the first week results in reduced farrowing and well-being measures compared to mixing after the fifth week, while mixing after the 2^{nd} week shows intermediate effects. When mixing sows, short term responses for well-being and long term measures for reproduction and well-being must be considered to evaluate the effects of housing management. Overall however, when examining the endpoint measures of reproduction and taking into consideration the classification of average well-being scores, our data suggests that in well-managed farms problems associated with day of mixing could have minimal impact.

Introduction

Concern about the welfare of housing gestating sows in stalls has given rise to legislative, industry, and consumer pressures to increase use of group housing systems. Recently, numerous US food retailers indicated they will soon require suppliers to end use of stalls in favor of loose housing systems. This will be an important change as most of the sows involved in commercial pork production (USDA-NASS, 2010) are housed in stalls in large environmentally regulated barns (PigCHAMP, 2010) that facilitate high productivity and efficient animal management (USDA-APHIS, 2006) with limited labor (Plain and Lawrence, 2003).

Mandated changes in future housing systems for sows could impact reproductive performance and animal welfare and assessment of new systems should include indicators of reproductive failure, animal stress and injury. Uniformed housing directives could have detrimental consequences for the sustainability of the US pork industry and result in reduced welfare for the sow. Conflicting evidence exists on the impact of mixing sows in early gestation on reproductive failure resulting from pregnancy disruption and increased fetal losses. Reproductive failure has been reported to increase in sows mixed in groups or exposed to stressors at weaning (Munsterhjelm et al., 2008) breeding (Einarsson et al., 2008) and before or after embryo implantation (Arey and Edwards, 1998). In contrast, no such reproductive failures have been reported for females mixed before estrus (Soede et al., 2007), within the first 10 days of gestation, or until 28 days following breeding (Bates et al., 2003; Cassar et al., 2008; van Wettere et al., 2008). Besides reproductive failure, studies have shown that individual housing in stalls improves the welfare of sows when compared with those mixed and housed in groups (den Hartog et al., 1993). Taking both measures into consideration, research suggests that reproductive failures occur more often in early gestation for group housed sows while problems related to welfare, such as incidence of lameness, appear more frequently with stall housing later in gestation (Karlen et al., 2007).

Project Objectives

The objectives of this study were to determine the effects of day of mixing sows into loose housing groups in pens following breeding on reproductive fertility and measures of animal well-being on a commercial farm during the summer months.

Materials and Methods

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.

Animals and Treatment

This study was conducted in replicates (n = 8) on a 6,000 sow, farrow-to-wean commercial farm in western Illinois during the summer months of June through August 2010. Sows assigned to treatment (n =1436) were of mixed parity (2-6) and were PIC C-22 and C-29 genetics. Groups of mixed parity (n = 58) sows were weaned on Monday-Saturday during the week. Following a 19-21 day lactation, pigs were weaned and sows moved into individual stalls in the breeding barn for detection of estrus. Sows were checked for estrus once daily in the AM using fenceline exposure to a mature boar. Once detected in estrus (d = 0), sows were inseminated at onset and at 24 h intervals until no longer standing. Insemination was performed using ~3.0 x 10^9 sperm/dose. At onset of estrus, sows were randomly assigned to one of four housing treatments: 1) stalls from weaning through gestation (Stall); 2) stalls from weaning until mixing at d 3-7 (D3 Mix); 3) stalls from weaning until mixing at d 13-17 (D14 Mix); and 4) stalls from weaning until mixing after d 35 (D35 Mix). Sows were mixed into pens as a group of 58 sows. For each treatment, sows were subsequently maintained in their final housing systems until ~ d 110 of gestation before they were moved into crates in the farrowing. Initial farm concerns about the D 14 Mix causing significant reproductive failure resulted in a design that used all treatments in the first week (replicate 1) followed the next week with all treatments except the D 14 Mix (replicate 2). This pattern repeated to allow 6 full and 2 partial replicates.

Housing and Feeding

The animals 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 that were 5.6 x 17.6 m which were on a fully-slatted concrete floor. Each pen contained one electronic sow feeder (Nedap Velos, Gronelo, Netherlands) and three water bowls. Animals housed in group pens with ~ 56 sows to allow ~1.74 sq. m. per sow. The facility also maintained gestation stalls (0.6 m x 2.1 m) used for housing sows during breeding and early gestation. Each stall was located over a fully slatted floor and was 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 20% dried distiller grains and each sow received 2.27 kg/day of feed from weaning until 100 days of gestation with adjustments given for body condition at d 30, d 60, and d 90 days of gestation. At d 100 of gestation, sows received an additional 0.9 kg increase.

Reproductive measures

Reproductive measures were assessed for all sows in all replicates. Conception rates were determined by trans-abdominal real-time ultrasound by the farm technician between d 28-32 of gestation. Farrowing rate, litter size (total born, born alive, stillbirths, and mummified fetus) and gestation length were recorded for each sow. Rebreeding data for treated sows that farrowed included the proportion of sows that expressed estrus within 10 d following weaning and the interval from weaning to estrus.

Well-being measures

Fighting events

For sows assigned to mixing, behavioral data was collected in 6 replicates to determine the number of fighting events that occurred within the first 23 h after mixing. On day of mixing (d 1), sows in pens were recorded using a fixed-mount digital camcorder (Sony Corporation of America, New York, NY) located above the pen to allow visualization of the entire pen. Recording began immediately before mixing and continued for 24 h. Upon video playback, aggressive interactions among sows were assessed for aggressive and submissive behaviors for classification based on the observation of: 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 one sow retreated. Interference from another pig was considered an additional fighting event. Pushes (given with head or shoulder) were also considered agonistic behaviors. The determination for the numerical measure for number of fights was adjusted for each treatment and replicate to account for differences in recording durations.

Lesions, leg assessment, body condition score

Animals from all treatments were observed in 6 replicates for lesions and BCS on days 3, 6, 9, 12 after mixing or movement into a permanent stall, and then biweekly thereafter until movement into a farrowing crate. Lesion score assessments included the head (including the neck), body (including the shoulder, back, side, rear, and udder), leg and vulva and were assessed based on the presence or absence of new or old lesions along with the severity of the wound. Lesion scores were defined as follows: None (score = 0, no lesions); Low (score = 1, few, moderate wounds, observed scabbing over scratch); Moderate (score = 2, numerous marked wounds, scratch red in color); and 3) High (score = 3, abundant fresh scratches, open/bleeding wounds). Vulva lesion scores were defined as: None (score = 0; no lesions); Moderate (score = 1, scabbing or abrasion, red in color), or High (score = 2, laceration, 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 was standing and began to walk. BCS was assessed using the visual-appraisal (sow's rear aspect) method described by Coffey et al. (1999), BCS (1 = lowest, 5 = greatest). The same individual recorded all scores.

Blood sampling for cortisol

To assess cortisol response to treatment, a baseline cortisol was obtained by collecting a single blood sample from a random population of 20 sows within each treatment prior to mixing or movement into a permanent stall. To assess the cortisol response to treatment, a sub-sample of sows from each treatment (n = 15) was randomly selected from sows with lesion scores classified as low, moderate, or high and serum obtained from sows (5/lesion class/treatment) on d 3 and d 9 following mixing or movement into permanent stall. To obtain blood, sows were snared and samples (4 mL) collected within two minutes via jugular vein puncture using vacutainer tubes between 0900-1100 h. Samples were allowed to clot at RT for one hour and then placed at 4˚C for 12 h before centrifugation at 400 x g at 4°C for 15 min. Serum was transferred into polypropylene tubes for storage at -20˚C until assay.

Hormone Assays

Cortisol was determined using a commercial RIA kit (Siemens Coat-a-Count, Diagnostic Products, Los Angeles, CA). Assays were performed according to the manufacturer. Serum was concentrated two-fold and used with the standard curve supplied in the RIA kit. If samples were off the curve because they were too high, they were re-run. If, after doubling the sample volume, the value was too low, the sample was reported as not detectable. The intra-assay and inter-assay CV were 7.3 % and 6.5 %, with a minimal detectable concentration of 2 ng/mL.

Statistical Analysis.

Sow data were collected and recorded using Agrisoft Ltd. and then exported into a spreadsheet before analysis of variance using SAS (SAS Inst. Inc., Cary, NC). Data for partial replicates were pooled with the full replicate from the week before to create an analysis with six experimental replications to determine the effect of treatment. Continuous response measures were analyzed using the PROC GLM procedures of SAS (SAS Institute, Cary, NC, USA) for significance of the main effects of treatment using the F-Test and differences between least squares means identified using the T-test. Binary response measures were analyzed using PROC GENMOD and significant effects of treatment and differences between least square means identified using the chi-square test. Analyses were performed for binary data (conception and farrowing rate, sows rebreed within 10 d, proportion of sows lame or with leg inflammation) using a binary distribution and a logit-link. For count data (fights) and proportion data (cortisol) analyses were performed using a poisson distribution and a log-link. The models for the reproductive responses included the main effects of treatment and replicate and parity as a covariate. For well-being measures, models included the effects of treatment, period, and the interaction term, replicate, and parity as a covariate. Well-being measures were analyzed by period 1 (observations obtained during the first 12 d after mixing or movement into permanent stall) or period 2 (observations made subsequent to d 12 until d 110 of farrowing). Cortisol was analyzed as a proportion change from the mean baseline measure for each treatment. The assumptions of analysis of variance for normal distribution of data were evaluated and tested using PROC UNIVARIATE and for homogeneity of variance using Levene's test. Data that could not meet the assumptions were transformed for analysis. Differences between means were significant at a $P < 0.05$.

Rank assessment

To help evaluate reproduction and well-being responses in combination, a ranking of the means was performed for each numerical response from best to worst and a rank sum created for each category of reproduction, well-being period 1 and well-being period 2.

Results

Reproductive measures

Reproductive measures are shown in Table 1. The average parity of sows assigned to treatment differed by treatment (P <0.0001) but averaged fourth parity for each treatment. Lactation length averaged 22.1 ± 0.1 d and number of inseminations 2.0 ± 0.004 and did not differ among treatments (P > 0.10). Conception rate was affected by treatment with the D3 and D14 Mix reduced (P< 0.05) compared to D35 Mix and Stall. Farrowing rate was also influenced by treatment with the D3 Mix reduced compared to D14 Mix, D35 Mix and Stall. Gestation length was not influenced by treatment and averaged 115.8 ± .04 d. The total number of pigs born (12.2 ± 0.1), born alive (11.5 ± 0.1), stillborn (0.60 ± 0.03) and mummified fetuses (0.08 ± 0.11) did not differ among treatments (P > 0.10). There was an effect of treatment on the percentage of sows that expressed estrus and were rebred within 10 d of weaning in the subsequent parity. Fewer sows in the D3 and D14 Mix treatments were rebred within 10 d of weaning compared to sows assigned to Stall while the D35 Mix did not differ from the other treatments. There was no effect of treatment the intervals from weaning to estrus which averaged 4.3 ± 0.05 d.

Well-being measures

There was an effect of treatment of the number of fights occurring within 24 h following Mixing (Table 1). Approximately 33% fewer fighting events were observed in the D14 Mix compared to the D3 and D35 Mix treatments. Cortisol change in period 1 relative to mean pre-treatment baseline was influenced by treatment (Figure 1) with all Mixed sows showing increases relative to Stall. The D35 Mix showed the greatest increase compared to the other Mix treatments (P<0.05). Treatment influenced the incidence of lameness (P< 0.0001) with sows in the mix treatments had a greater incidence of lesions (10.1%) than those in stalls (3.1%) but did not differ from one another. Lameness was also affected by period and was slightly higher in Period 1 (8.4%) than period 2 (6.9%). There was a treatment x period interaction and Stall and D14 Mix sows showed no change by period, while lameness increased in D3 and decreased in the D35 Mix (Figure 2). For leg inflammation, there was effect of treatment (P<0.0001) with inflammation lowest in the D35 Mix (1.5%), higher in the D 14 Mix (2.7%) and Stall (3.7%) and highest in the D3 Mix (5.6%) compared to the other treatments (P<0.05). There was no effect of period and incidence of lameness averaged 3.0% but there was a treatment x period interaction (P< 0.0001). Sows in Stall and D 14 Mix did not change by period while inflammation increased in D3 Mix and decreased in the D 35 Mix (Figure 3). Lesions were scored for head, body and vulva and all showed an effect of treatment, period and a treatment x period interaction. Head and body lesion scores differed among all treatments with average scores greatest for D3 (1.4), D14 (1.3), and D35 (1.2) Mix treatments compared to Stall (0.7). Lesion scores were greater on average in period 1 (1.3) than period 2 (1.0). There was a treatment x period interaction for head and body lesions. For head and body lesions, Stall showed a slight increase while all Mix treatments showed reductions from period 1 to period 2 (Figures 4 and 5). For vulva lesions, all treatments differed with D3 greatest (0.22), followed by Stall (0.20), D 35 (0.14) and D 14 Mix (0.13). In contrast to other lesion scores, vulva lesions increased in period 2 (0.16) compared to period 1 (0.11). There was a treatment x period interaction for vulva lesions, there was no change in Stall or D 14 Mix, while D3 and D 35 Mix showed increased lesions from period 1 to 2 (Figure 6). Body condition score was affected by treatment and was lower in D3 Mix (2.80) than D 14 Mix and Stall (2.85) compared to D 35 Mix (2.94). Body condition score was also lower in period 1 (2.8) compared to period 2 (2.9). There was a treatment x period interaction as BCS increased in stalls, D3 and D14 Mix but did not change in the D 35 mix from period 1 to 2 (Figure 7).

A rank score assessment of reproductive and well-being is shown in Table 3. The rankings revealed that in all categories, mixing at D3 resulted in the poorest scores for reproduction and well-being measures while, followed by the D14 Mix, and then the D35 Mix. Stall housing resulted in the best performance for all measures.

Discussion

The results of this experiment demonstrate that both reproduction and well-being are affected by day of mixing even in well-managed group housing systems. Mixing sows into groups after breeding on specific days resulted in short term and long-term reproductive performance failures. Similar effects were observed for animal well-being in response to day of mixing into groups, with short term changes in fighting, cortisol, lesions and lameness scores and long-term measures of lesions and lameness. Our ranking of the responses for reproduction and well-being allowed us to select a system that was best for reproduction, well-being and the combination. Our results showed that ranking order was the same for each category and that stall housing was ranked best, followed by mixing after the fifth week, mixing in the third week and then mixing in the first week. Despite the fact that reproductive and well-being measures were affected by day of mixing, it is important to call attention to the fact that all treatments measures for reproduction met or exceeded current industry reproduction targets for farrowing rate, litter size, and sows bred within 7 days of weaning (PigCHAMP, 2010). For reproduction this is notable since the study was conducted in the summer when increased reproductive failures are frequently reported (Knox and Zas, 2001; Koketsu et al., 1997; Love, 1993; Xue et al., 1994). Measures of animal well-being included one measure that is part of the Pork Quality Assurance Program (PQAplus, National Pork Board, 2012). This included the proportion of breeding sows with a body condition score of one. The level for need for improvement is at 1% of assessed animals, and in this study for all treatments, this measure was below 1%. Other measures not part the assessment program but for which guidelines are included in the educational materials, address the percentage of breeding animals with lesions and those showing evidence of lameness. Our study used a graded classification system for many measures and indicated that day of mixing and period showed interactions for frequencies of lesions and lameness. Overall however, when examining the endpoint measures of reproduction and taking into consideration the classification of average well-being scores, our data suggests that in well-managed farms problems associated with day of mixing could have minimal impact.

Reproductive performance is a key measure for profitability for swine farms (Britt, 1986) and reproductive failure is a leading reason for sow culling (Koketsu et al., 1997; USDA-APHIS, 2006) which results in lowered herd productivity and reduced sow longevity (Koketsu et al., 1999). The causes of reproductive failure are often unknown, but have been associated with certain types of stress, seasonality and disease (Britt et al., 1999; Tubbs, 1997). Reproductive failure associated with housing stress is of great interest and importance as new state legislation and requirements by many commercial food retailers now direct producers to use group housing of sows. As a result producers that decide to remain in business will need to remodel facilities and devise a management plan for creating groups of sows after leaving the farrowing facility. While there is uncertainty as to when mixing of sows should occur after breeding to avoid reproductive failure, most recommendations suggest that sows should never be mixed at the time implantation (Schwartz, 2011; Von Borell et al., 2007). Our results showed lowered conception rates as a result of mixing in the first or third week after breeding when compared to late mixed sows or those in stalls. This translated into reduced farrowing rates for sows mixed in the first week compared to late mixed and stall hosed sows. But for sows mixed in the third week at implantation, farrowing was not reduced compared to later mixed sows but was lower than those sows housed in stalls. We did not observe a reduction in farrowing rate for late mixed sows compared to those housed in stalls. There is a considerable amount of conflicting data for the effects of housing and mixing stress on reproductive responses. Lang et al. (2004) reported that stress applied at critical times of the cycle could impact reproductive processes and Arey and Edwards (1998) noted that stress from mixing at time of implantation results from aggression, cortisol increase, and leads to pregnancy failure and loss of embryos. Stress in group housed gilts from restricted floor space was reported to reduce fertility (Hemsworth et al., 1986). Group housing itself in comparison to individual housing, results in reduced conception rates and higher sow culling especially with respect to seasonal fertility (Hurtgen and Leman, 1980). Munsterhjelm et al. (2008) reported that disruption of pregnancy was more likely in group housed sows compared to housing in stalls and Estienne et al. (2006) reported that mixing groups of gilts immediately after AI increased lesions and reduced pregnancy rates. The problems in group housing that result in a reduction in fertility (den Hartog et al., 1993) have been associated with problems in feeding and body measures in the first three weeks of gestation (Kongsted, 2006) when compared to sows in individual housing. Others suggest that feed intake problems in mixed groups is a result of social rank and competition at electronic sow feeders (Kranendonk et al., 2007). Einarsson et al. (2008) suggests that these types of stress can negatively affect an animal by diverting energy resources away from certain biological functions including immune function, growth, metabolism and reproduction. For reproduction, processes that depend upon precise hormonal changes are considered especially susceptible and include follicle growth, ovulation and early gestation.

In contrast to our observations and the previously cited studies, numerous reports also suggest no effect of housing or mixing stress on measures of reproduction. While one report indicates improved reproduction in groups compared to individual housing (Bates et al., 2003) most show no effect. Harris et al. (2006) reported no effect of group housing compared to individual housing on reproduction even though lesions and lameness were observed to be greater with group housing. It is worthy to note that in this study, the authors indicate the quality of the stall was superior and the quality of the pen. Salak-Johnson et al. (2007) noted no effect on reproduction in group housed sows with limited floor space throughout gestation. Turner et al. (2005) observed that acute or sustained stress or short term food deprivation at implantation, had no effects on pregnancy or number of embryos. van Wettere et al. (2008), Soede et al. (2007) and Cassar et al. (2008) mixed gilts or sows in groups at various days after breeding and observed no effect on pregnancy rate or litter size even though fighting events were increased. As a result, some authors concluded that mixing unfamiliar females can be performed in early gestation without reproductive problems. With groups of 30 sows, mixing in dynamic versus static group management with an ESF system, there was no observed effect on reproduction compared with stalls even though the welfare was reduced in the dynamic system (Anil et al., 2006). Recent industry reports relay that group housing systems in North America work well compared to stall housing (Parsons, 2011) and that early mixing in the first week and late mixing after d 30 work well but that mixing at implantation is not practiced due to potential losses (Schwartz, 2011).

The discrepancy for why some studies report reproductive failure others do not as a result of group housing or mixing could be influenced by any number of variables. These could include the age and maturity of the animal, herd parity, season of the year, day of mixing, group size, floor space, pen design, group integrity, and feeding system, to name just a few. Further, despite the effects we observed in this study, others may not have observed similar effects due to the inclusion of controls as the late mix and stalls treatments within experiment. The two controls allowed us to determine consistent effects on reproduction and welfare. Our approach to evaluate reproduction and welfare measures in combination using all of our measures helped us use a simple ranking system. Others have used index scoring systems for reproduction and welfare to evaluate housing systems for sows as well. Bracke et al. (2002) reported a ranking systems that relied extensively on sow environment and opinion in which the stall ranked very low due to a weighted scoring system based on available space, forage availability, allowance for rooting, wallowing, and separate areas for resting and eating. Munsterhjelm et al. (2008) also reported on the use of an index for reproduction and welfare and observed that scores were weighted towards housing environment and not lesions or lameness. Karlen et al. (2007) compared sows in stalls and groups, and observed group housing was associated with more lesions, higher returns to estrus following breeding, and increased cortisol after grouping. Stall housing showed a small increase in lameness in late gestation and altered immune function as an indicator of increased stress effects on health.

While the majority of the reports have focused on pregnancy and farrowing failures, it is important to acknowledge that there were no effects on litter size in the present study, and limited reports of any effect of stress from mixing on litter size. This provides strong evidence for a limited effect of these types of stressors on early embryo loss. However, we did note an effect of treatment for sows that farrowed to return to estrus to be mated within 10 d of weaning. Sow longevity in the herd has recently received much attention as it relates to profitability and sow welfare. Reproductive failure is often listed as the primary or secondary reason for culling with conception failure and failure to express estrus for breeding as the leading reasons for removal (Britt, 1986; Heinonen et al., 1998; Koketsu et al., 1997; Tubbs, 1997). Fewer sows that were mixed in the first or third week after breeding returned to be mated after farrowing compared to sows in stalls and would be an important indicator for longevity (Koketsu et al., 1999). Although there were no meaningful differences in body condition score in period 2, it is possible that the housing system may have affected body measures we did not measure in gestation which may have affected performance in lactation and following weaning.

Measurement of sow well-being is important since several states now regulate sow housing and food retailers have directed their supplies for loose sow housing based on animal welfare reasons. Animal well-being can be measured by numerous ways and different systems for evaluation are in use with some weighted toward the perception of the environment and other weighted more toward measures of the animal (Bracke et al., 2002; Karlen et al., 2007; Munsterhjelm et al., 2008; National Pork Board, 2012). In the present study we chose to assess measures in use by the industry (National Pork Board, 2012) and in research assessments (Salak-Johnson et al., 2007). Our study included measures of lameness, a leading reason for sow culling (USDA-APHIS, 2006), fighting events, lesions scores, cortisol and body condition score soon after mixing or movement in to their permanent stalls (period 1) or in the longer term period (period 2). We observed differences in all measures in response to treatment and observed interactions of treatment with period. In period 1 we measured fighting in the 24 h period after mixing and observed 33% more fights in the groups mixed in the first and after the fifth weeks than those mixed during the third week of gestation. It is not clear why more fighting events occurred in these two groups as they would seem to be dissimilar in their experience and reproductive states. Fighting is reported to result from behaviors to establish social hierarchy and can be influenced by the feeding system, size of the animal, previous exposure to other group members, size of the group and pen design to name a few. Cortisol increase was greatest in the late mix group and was moderately increased in the other mix groups compared to stalls. Several reports have indicated that cortisol increases in sows in response to mixing stress (Hemsworth et al., 1986; Jansen et al., 2007; Karlen et al., 2007). However, others report no effect of housing stress on cortisol (Anil et al., 2006; Soede et al., 2006) or report increased cortisol in individually housed but not group housed females (Estienne et al., 2006; Karlen et al., 2007). Chronic stress from social and movement restrictions have been associated with gestation stalls (Von Borell et al., 2007) but that cannot be substantiated in the present study. Compared to 4% of sows in stalls scored as lame in period 1, we observed 15% of sows in the late mix group lame and ~9% in the other groups. In period 1, lesion scores on the head and body increased from an average in stalls between no lesions to low to an average of low to moderate in the mixed groups. Vulva lesions were increased in mixed sows compared to stalls but incidence was very low in all. Body condition score in period 1 differed slightly and the score was most likely related to the days that sows were individually fed before evaluation. Without reference to specific days or periods, previous reports have noted that gilts or sows mixed after mating show increased fighting, lesions, scratches and cortisol compared to those maintained in stalls (Estienne et al., 2006; Jansen et al., 2007; Karlen et al., 2007). However, in period 2, in the period from 12 days after mixing or in their permanent stall until farrowing, many of the measures changed for lesions and lameness and suggested that short and long term measures of welfare may help evaluate the management for group housing of sows. As gestation progressed sows mixed in the first week and with a longer time spent in the group pen, showed a 5% increase in lameness, while sows mixed after the fifth week showed a decrease in lameness. Lameness was low in stalls and in the late mix groups compared to the groups mixed in the first or third weeks and appears related to duration of time spent in pens. Leg inflammation while not different in period 1 showed effects in period 2 and was highest in sows mixed in the first week and lowest in late mixed sows. Head and body lesion scores were lowest for sows in stalls and increased only slightly from period 1 to 2, while lesions declined all sows in the mix treatments. Vulva lesions were notably higher in period 2 in sows mixed in the first week and to a small extent for sows in the late mix treatment. Collectively, the well-being measures point to the stall as a method to improve many physical measures of well-being as well a tool to reduce stress, cortisol and fighting. The data also point to the fact that day of mixing after breeding or the duration of time sows spend in pens affects welfare. This seems to be the opposite of research that suggests sows housed for long periods of time in stalls are believed to have increased levels of lameness (Karlen et al., 2007).

An optimal management system for gestating sows may not be possible as there are far too many variables in the type of housing systems that can impact reproduction and animal well-being. With this many variables it is not possible to control all factors, but systems that address reproduction and well-being will aid in the economic sustainability of the farm while dedication to animal welfare is essential for animal health and public approval. It is our conclusion, that the conception failure and farrowing failure were increased and animal welfare was poorest when sows were mixed in the first week after breeding. Mixing sows in the third week at implantation did not result in reduced farrowing rates or increased embryo losses and animal welfare was intermediate. Mixing sows after the fifth week following breeding resulted in reproduction rates most similar to sows maintained in stalls and even though well-being in the short term was not optimal, long-term well-being was good. Management of sows in stalls resulted in the best reproductive performance and best measures for animal welfare. Efforts to improve animal welfare and productivity should consider strategic use of the sow stall rather than elimination of the device from production settings.

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Table 1. Least squares means (± SE) for reproductive measures for weaned sows housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen.

	Stall	D3 Mix	D14 Mix	D35 Mix	*P*-value
Replicates	6	6	4	6	
Sows	158	463	347	464	
Parity	4.4 ± 0.1^{ab}	4.6 ± 0.1^{a}	4.3 ± 0.1^{b}	4.2 ± 0.1^{b}	<0.001
Lactation length, d	21.5 ± 0.3	22.0 ± 0.2	21.8 ± 0.2	21.8 ± 0.2	0.63
Number of services / sow	1.96 ± 0.01	1.96 ± 0.01	1.97 ± 0.01	1.97 ± 0.02	0.96
Conception rate, %	96.2 ± 4.2^{a}	87.1 ± 1.4^{b}	89.2 ± 1.7^{b}	92.2 ± 1.8^{a}	< 0.005
Farrowing rate, %	92.8 ± 3.1^{a}	82.8 ± 1.3^{b}	87.8 ± 1.6^{a}	90.5 ± 1.6^{a}	<0.0001
Gestation length	115.9 ± 0.1	115.8 ± 0.1	115.9 ± 0.1	115.9 ± 0.1	0.35
Total born / litter	12.4 ± 0.3	11.9 ± 0.2	12.4 ± 0.2	12.2 ± 0.2	0.30
Pigs born / litter	11.8 ± 0.3	11.3 ± 0.2	11.6 ± 0.2	11.5 ± 0.2	0.50
Stillborn pigs	0.59 ± 0.08	0.53 ± 0.05	0.65 ± 0.06	0.63 ± 0.05	0.62
Mummies	0.06 ± 0.03	0.08 ± 0.02	0.07 ± 0.02	0.04 ± 0.02	0.44
Sows re-bred within 10 days, %	96.6 ± 5.1^{a}	90.4 ± 2.3^{b}	88.8 ± 2.1^{b}	93.0 ± 2.2^{ab}	0.04
Wean to estrus interval for sows rebred within 10 days	4.5 ± 0.1	4.3 ± 0.1	4.2 ± 0.1	4.3 ± 0.1	0.23

[a-d] Within a row, means without common superscripts differ (P < 0.05).

Table 2. Least squares means (± SE) for number of fighting events for weaned sows housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen.

	Stall	D3 Mix	D14 Mix	D35 Mix	*P*- value
Replicates	6	6	4	6	
Number of sows, n[1,2]	158	463	347	464	
Fights per 24 h following mixing[1]	-	125.4 ± 19.2[a]	84.2 ± 23.0[b]	125.1 ± 19.2[a]	< 0.0001

[1] Number of sows observed for fighting events.
[2] Aggressive encounters were for sows assigned to mixing groups. All fighting events were adjusted to 24 h of total video due to variation in duration of video recordings.
[a-d] Within a row, means without common superscripts differ (P < 0.05).

Table 3. A sum ranking for assessments of increased levels of reproductive performance and improved measures of animal well-being.

Treatment	Reproductive response sum[1]	Well-being response sum Period 1[2]	Period 2[3]	Total sum	Final rank[4]
Stall	3	10	8	21	1
D3	11	24	18	53	4
D14	9	22	13	44	3
D35	7	18	12	37	2

[1]included farrowing rate, litter size and sows rebred

[2]includes fights, cortisol, lameness, inflammation, lesions (head, body, vulva), and body condition score

[3]includes lameness, inflammation, lesions (head, body, vulva), and body condition score

[4]best possible score (18) from rank of 1 for each measure and worst possible score (72) from rank of 4 in all 18 categories.

Figure 1. Least squares means (± SE) for fold change in mean cortisol relative to pre-treatment baseline for weaned sows housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stalls until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. Cortisol measurements were obtained on day 3 and on day 9 from a random sub-sampling of sows from all lesion score classes (n = 15 sows / treatment) following mixing, or movement into permanent stall. There was an effect of Treatment ($P < 0.0005$). Means without common superscripts differ ($P < 0.05$).

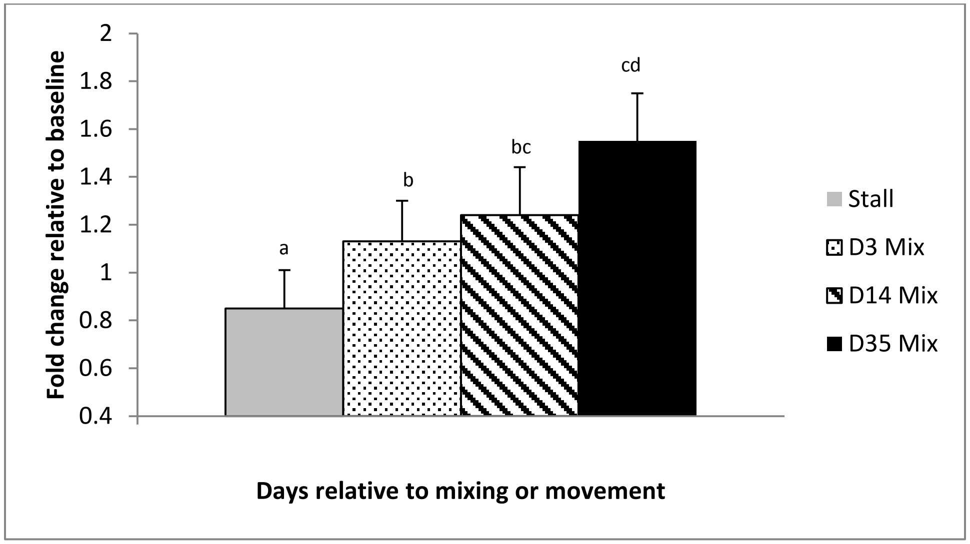

Figure 2. Least squares means (± SE) for the percentage of weaned sows that showed lameness when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) and Period ($P < 0.05$) and a Treatment x Period interaction ($P < 0.0001$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$).

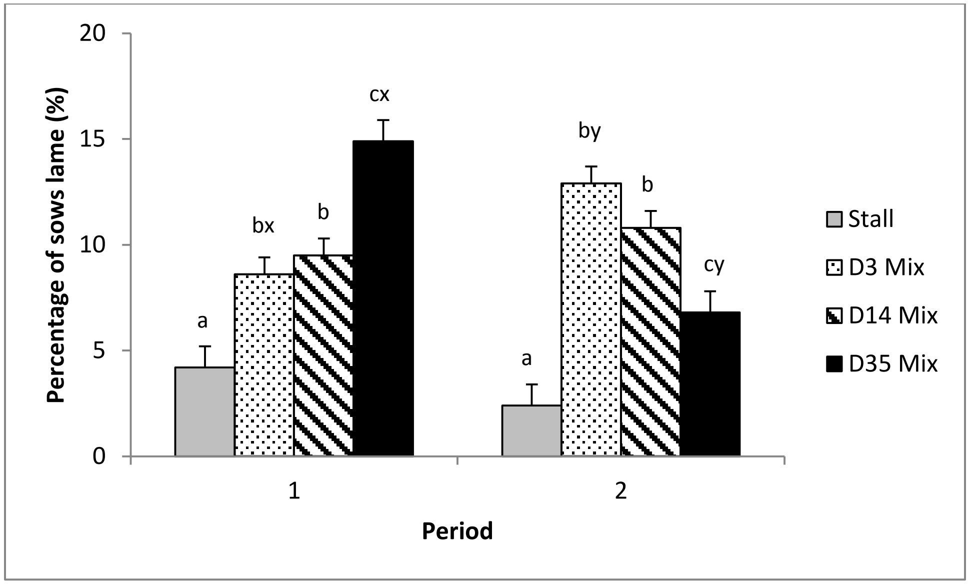

Figure 3. Least squares means (± SE) for the percentage of weaned sows that showed leg inflammation when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) but not Period ($P > 0.10$) but there was a Treatment x Period interaction ($P < 0.05$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$).

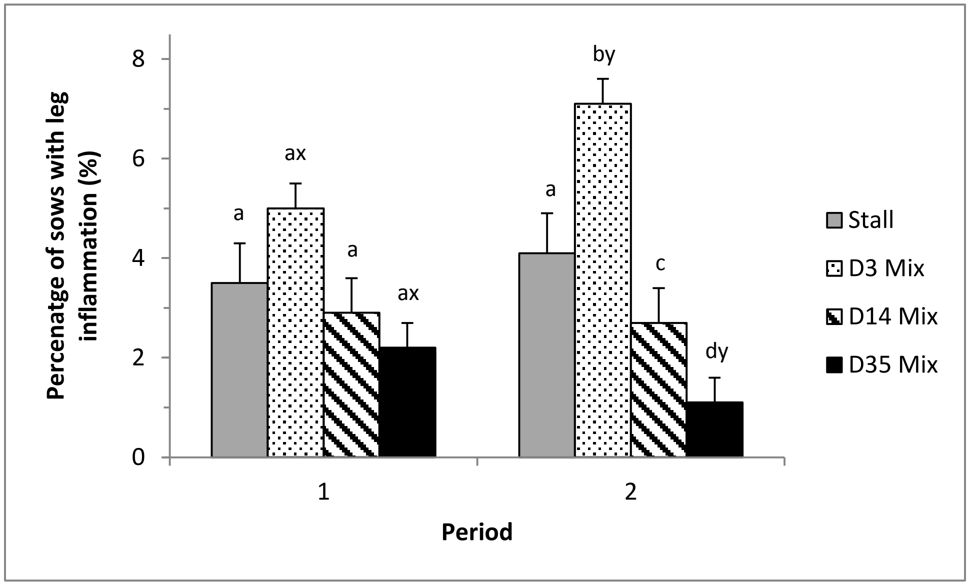

Figure 4. Least squares means (± SE) for the percentage of weaned sows that showed head lesions when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) and Period ($P < 0.001$) and a Treatment x Period interaction ($P < 0.0001$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$). Lesion scores were defined as follows: None (0); Low (1, few, moderate wounds, observed scabbing); Moderate (2, numerous marked wounds, red in color); and 3) High (3, abundant fresh scratches, open/bleeding wounds).

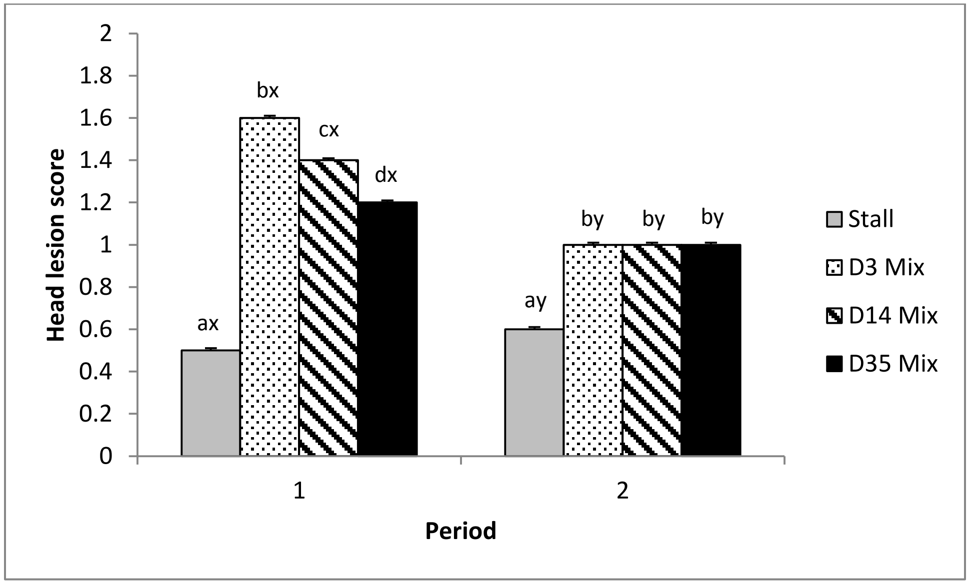

Figure 5. Least squares means (± SE) for the percentage of weaned sows that showed body lesions when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) and Period ($P < 0.0001$) and a Treatment x Period interaction ($P< 0.0001$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$). Lesion scores were defined as follows: None (0); Low (1, few, moderate wounds, observed scabbing); Moderate (2, numerous marked wounds, red in color); and 3) High (3, abundant fresh scratches, open/bleeding wounds).

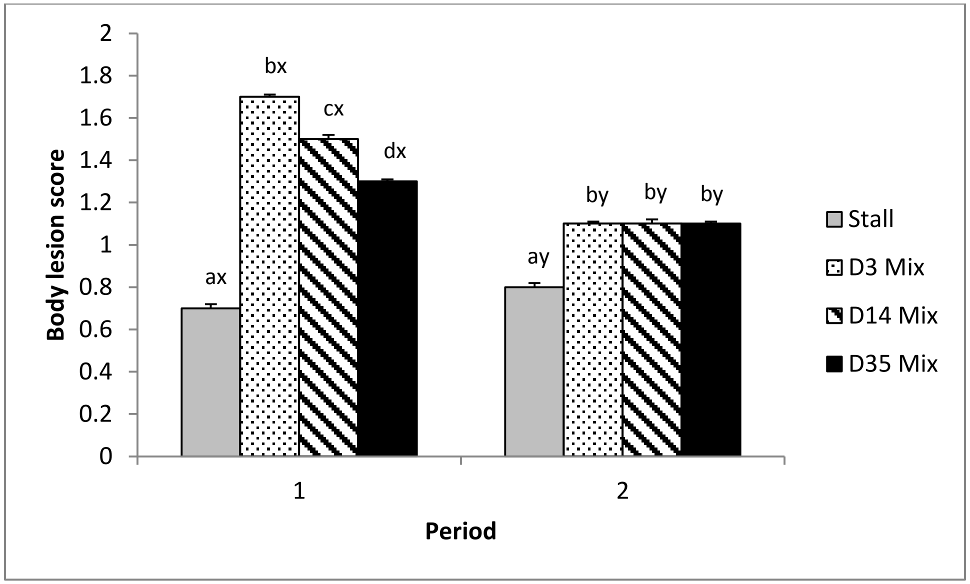

Figure 6. Least squares means (± SE) for the percentage of weaned sows that showed vulval lesions when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) and Period ($P < 0.05$) and a Treatment x Period interaction ($P < 0.0001$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$). Vulva lesion scores were defined as: None (0); Moderate (1, scabbing or abrasion, red in color), or High (2, laceration, bleeding).

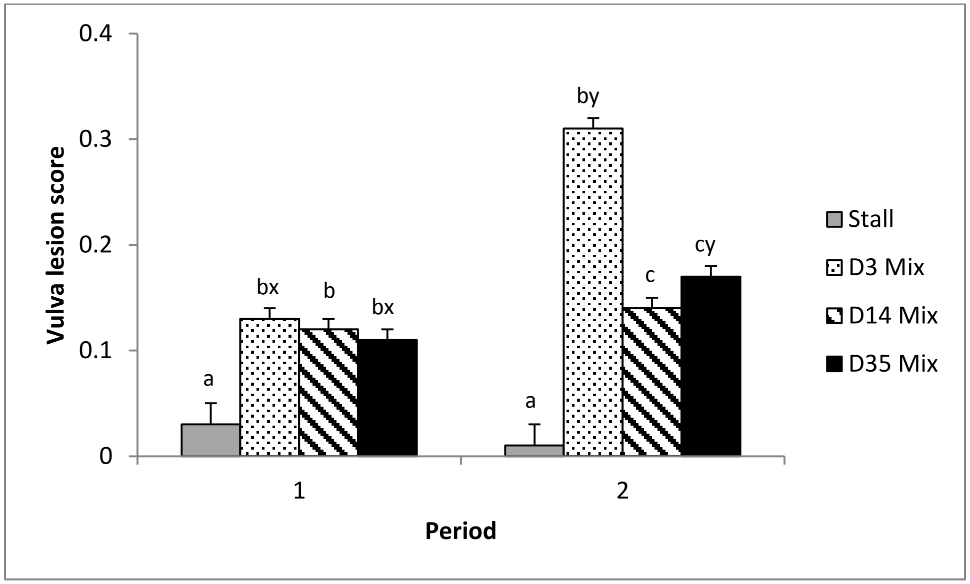

Figure 7. Least squares means (± SE) for the body condition score (BCS) of weaned sows when housed in stalls only (Stall), stalls until Days 3 to 7 (D3 Mix), stall until Days 13 to 17 (D14 Mix), or stalls until Day 35 (D35 Mix) of gestation before mixing into groups of 58 sows/pen. All sows were observed on Days 3, 6, 9, 12 (Period 1), and then bi-weekly until farrowing (Period 2) following mixing, or movement into permanent stall. There was a significant effect of Treatment ($P < 0.0001$) and Period ($P < 0.0001$) and a Treatment x Period interaction ($P < 0.0001$). Means without common superscripts between treatments within a period (a-d) and within a treatment between periods (x-y) are different ($P < 0.05$). BCS was assessed using visual-appraisal with 1 = low and 5 = high.