RESEARCH REPORT

ANIMAL WELFARE

Title: Influence of Gestation Housing on Sow Welfare and Productivity – **NPB #03-055**

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Abstract

In four experiments, the effect of the group housing of gestating sows and concurrent boar contact on sow aggression, salivary cortisol concentrations, body condition, and fertility were examined. In experiment 1, 96 sows at 65-70 days of gestation were assigned by parity to be housed individually or as groups. Group-housed sows were involved in more aggressive encounters (AGG) than stall-housed animals (P<0.05) and in grouped sows, AGG were more numerous during feeding than during the day of grouping (P<0.001). Salivary cortisol concentrations were higher in grouped sows but differences between pre-and post-mixing concentrations were not correlated with levels of aggression.

In experiment 2, 937 mixed parity sows in 10 weekly breeding groups were either grouped (n=462) or housed in gestation stalls (n=475). Sow management was as for experiment 1. For 140 individually-housed and 330 group-housed sows ('observed sows'), backfat depths at the P2 position were determined at 55-60 d of gestation, at farrowing, and at weaning using A-mode ultrasonography. There was no effect of housing on backfat depth at farrowing and weaning or on farrowing rate but grouping of sows was associated with smaller litters (P=0.04).

In experiment 3, 1,584 sows were relocated to outdoor paddocks after breeding as groups of approximately 50 with or without the inclusion of 3 mature boars. Farrowing rates were not affected by boar exposure. Litter sizes were increased in boar exposed sows (P=0.035).

In experiment 4, 309 mixed parity sows were housed individually or as groups of 12, with grouping being done at 2, 7, 14, 21, or 28 days of gestation. For 7 days after grouping, sows had either direct or fenceline boar contact or no boar contact. No significant effect of boar exposure or day of gestation was noted for farrowing rate or litter size.

Taken together, these data indicate that if sows are to be grouped during gestation, particular attention should be directed toward feeding management to avoid excessive aggression. Adverse effects of grouping (or aggression) on litter size may be ameliorated by direct boar contact in the immediate post-mixing period.

Introduction

The primary objective of the breeding herd is to cost effectively maximize the number of pigs weaned per sow (or farrowing crate) per year. A more basic objective is the meeting of consumer demand (English and Edwards 1999). The most common housing system for weaned and gestating sows in North America is individual stalls, which allow for ease of mating and for individual feeding. However, there is an increasing public perception that sow gestation crates are not "welfare-friendly" and a future consumer demand may be that pregnant sows be housed in groups. The challenge for the swine industry will be the maintenance of sow productivity while meeting the consumer objective for group housing. There has been considerable earlier research on the impact of group housing of pregnant sows. However, previous workers have tended to employ few sows, housed in small groups, and usually with some sort of individual feeding system (e.g. see Edwards 1992; den Hartog et al. 1993; Broom et al. 1995; Bates et al. 2003). The use of individual feeding systems will significantly add to the cost of a retrofit of existing operations, and is not consistent with the feeding behavior of domestic sows. We are not aware of any studies of sow performance comparing large sow groups to individual housing under commercial conditions using group feeding. Although research to date has demonstrated that group housing is a viable option for gestating sows (eg. Broom et al. 1995), there is a paucity of data regarding low cost options within existing facilities.

An advantage of group housing systems is that, although more space per sow is required, construction costs are lower. Also, anecdotal evidence indicates that groups of pregnant sows are easier to manage, require less labor input, and are beneficial to worker morale. Perceived disadvantages include; an inability to control individual sow feed intakes leading to a greater variation in sow body condition that may adversely impact lactation performance and subsequent fertility and, ultimately, result in earlier culling. Also, the grouping of unfamiliar pregnant sows will result in considerable aggression during the establishment of the social hierarchies (Mendl et al. 1992; Arey and Edwards 1998). In addition to posing a welfare risk from injuries, the stress associated with the aggression may reduce sow fertility (Kongsted 2004), which in turn may result in earlier culling.

Feeding sows in a group may result in greater variation in body condition due to dominant sows consuming more feed than subordinate sows, and also possibly as a consequence of chronic social stress (Mendl et al. 1992). What has not been addressed is whether this increased variation in sow body condition will actually impact herd performance. Ignoring extremes of body condition that warrant individual attention; we know that thinner sows will compensate with an increased feed intake during lactation with possibly no overall impact on fertility. We also know that fatter sows may have a reduced appetite during lactation resulting in a greater loss of backfat. While not feed-efficient, this voluntary feed restriction may not adversely affect fertility. However, these latter statements remain to be examined in controlled studies.

It has been suggested that stress and/or elevated circulating cortisol levels will not impact sow fertility unless relatively prolonged (Turner et al. 2002). However, due to the expectation of prolonged stress due to aggression when first grouped, and the belief that this stress will reduce sow fertility, the field recommendation is that sows not be moved or mixed before the completion of placentation (ca. 28 days; Arey and Edwards 1998). It is believed that mixing after this time will minimize any effect of stress on the maintenance of pregnancy. However, we are aware of no experimental data to confirm this suggestion. Further, if such an effect were demonstrated, the effect of stage of pregnancy when mixed would need to be defined.

Some degree of aggression is inevitable when unfamiliar sows are mixed and so information is needed on how to reduce the amount of aggression. Chemicals have been used with some success (eg. Gonyou et al. 1988; Barnett et al. 1993), but non-pharmacological approaches are required. It is known that the submaxillary salivary glands of boars release pheromonal steroids and that if these glands are excised gilts were more aggressive towards the boar (Perry et al. 1972). More recently, data indicate that the inclusion of a boar in a newly formed group of barrows and/or gilts (Grandin and Buning 1992; Barnett et al. 1993), or boar pheromonal steroids (McGlone and Morrow 1988), reduced the number of aggressive interactions. The potential utility of boar inclusion in newly formed sow groups requires further investigation.

Objectives

The objectives of these experiments were to:

1. Characterize agonistic interactions in large groups of pregnant sows (experiment 1)
2. Measure body condition changes and fertility in large groups of pregnant sows (experiment 2)
3. Determine the effect of boar presence after mixing on sow fertility (experiments 3 and 4)
4. Test the effect of boar presence during the post mixing period on the occurrence and severity of agonistic interactions in group-housed sows (experiment 4)
5. To define a stage of gestation at mixing that minimizes adverse consequences for sow fertility (experiment 4)

Experiment 1 (objective 1)

Material & Methods

Animals and Housing

This study was performed on a commercial 3,000-sow farrow-to-wean intensively housed sow herd. Sows were weaned into individual gestation stalls and had 5 min of nose-to-nose contact with a boar each day starting the day after weaning. Sows were artificially inseminated with 3 x 10^9 sperm in the presence of a boar at the detection of estrus and then at 24 h intervals if still exhibiting estrous behavior. Pregnancy was confirmed by trans-abdominal real-time ultrasound at 25 days after insemination. For the study, 96 sows (parity 0, 1, and $\geq$3) were assigned at 65-70 days of gestation in a 2 x 3 factorial design with housing environment (group vs. stall) and parity (0, 1 and $\geq$3, abbreviated as P0, P1 and P3, respectively) as parameters in four replicates. For each replicate, 24 sows were selected based on parity (4 animals per parity within treatment). Prior to relocation, all sows were individually identified using black hair-dye and confirmed to be pregnant by trans-abdominal real time ultrasonography. Boars were not present during the mixing period.

The 12 sows in the group-housing environment were mixed with 38 other sows to form groups of 50 (average parity for replicates 1, 2, 3 and 4 were 3.0, 2.3, 2.9 and 2.9, respectively). The groups were housed in rectangular pens (approximately 70% slats, 30% concrete flooring, 1.75 m^2/sow). The stall-housed animals were relocated in such order that all animals were housed adjacent to an unfamiliar animal within the same treatment in increments of 4 (i.e. buffer sow, 4 treatment sows, buffer sow, 4 treatment sows, etc). Food was provided twice daily (at 05:30 and 11:30 h) for sows in both group and individual housing. Group-housed sows were floor-fed by approximately 35 feeders dropping food in three feeding lines. Group-housed animals were provided water ad libitum by nipple drinkers in the pen, while stall-housed sows were given water approximately 3 x daily in a watering gutter.

Behavioral Observation

All experimental animals were observed for 2-days following relocation in three 1.5-hour time blocks (06:00, 09:00, and 12:00 h). All fights (defined as the reciprocal occurrence of head knocks and/or bites) and attacks (defined as the one-sided occurrence of head knocks and/or bites) involving the experimental animals within these time blocks were recorded. On the third day after relocation, feeding time aggression was observed for 30 min starting at the moment the feed was dropped. Prior to analysis, the total number of active aggressive encounters (attacks and fights; ACT), passive aggressive encounters (received attacks; PAS), and the total number of aggressive encounters (active and passive encounters; AGG) were calculated. Feeding time aggression was corrected for duration of the observation blocks (1 h of feeding time observation vs. 9 h of post-relocation observation) by multiplying all values by 9.

Lesion Scoring

One day before relocation and on the day after relocation, all experimental animals were lesion scored. Lesion scoring was done in a weighted fashion where minor skin abrasions were scored as 1, small punctures scored as 2, and bigger open lesions scored as 3. All lesions were scored separately for the front (defined as the part from the back of the front leg forward) and the back. The difference between pre- and post-relocation lesion scores was calculated prior to being analyzed.

Saliva Sampling and Cortisol Analysis

Saliva samples were taken one day before mixing and on the day after relocation at 05:00, 08:00, 11:00, and 14:00 h by inserting a piece of gauze attached to a rubber tube into the mouth of the sow until thoroughly moistened. Of every 4 animals, 3 were sampled. The gauze was then stored in a centrifuge tube and kept at -4°C until centrifugation. The samples were centrifuged at 3,000 RPM for 5 min and the saliva then transferred to 1.5 mL Eppendorff tubes and stored at -20°C until analyzed. Salivary cortisol concentrations were determined by Coat-a-Count radioimmunoassay, modified for use in pigs (Ruis et al. 1997).

Statistical Analysis

All analyses were performed using SAS 8.2 (SAS Institute Inc., Cary, NC, 2001). Data were checked for normality and found normal. The differences between pre- and post-relocation salivary cortisol levels were determined for each pair of samples and effects of housing environment (group vs. stall), parity (0, 1, 3) and their interactions were analyzed using a general linear mixed model (GLMM), allowing for random effects of pen, animal and replicate. For analysis, each series of 4 stalls was considered a pen for the stall-housed animals.

Effects of housing environment, parity and their interactions on lesion scores were analyzed using a paired t-test. Effects of housing environment, parity and their interactions on behavior were analyzed using a GLM allowing for random effects of pen and replicate, where for the stall-housed sows each group of 12 animals was considered as 1 pen. Correlations between lesions scores, cortisol concentrations and aggressive encounters were analyzed using Spearman's correlation test. Differences between feeding time aggression and aggression on the day after relocation were analyzed using a paired t-test.

Results

Behavior

There was no effect of housing environment on the number of post-relocation active aggressive encounters (ACT). Group-housed animals (8.54 ± 1.20) did not fight with other animals more often than stall-housed animals (7.17 ± 1.31; $P=0.30$). Parity did affect ACT, both in group-housed ($P<0.01$) and stall-housed sows ($P<0.001$). P0 sows fought significantly less than P1 ($P<0.001$) and P3 ($P<0.001$) animals, both in groups and in stalls (Figure 1).

The total number of aggressive encounters (AGG) was affected by housing environment, with group-housed sows (16.69 ± 1.29) being involved in more aggressive encounters than stall-housed animals (11.92 ± 1.83; $P<0.05$). Parity affected AGG differently in group- and stall-housed sows (Housing Environment x Parity; $P<0.01$). Whereas in group-housed sows no differences between sows of different parity could be found, P0 animals in stalls were involved in fewer aggressive encounters than P1 ($P<0.001$) and P3 ($P<0.01$) animals (Figure 2).

AGG in group-housed sows was higher during feeding time (30.00 ± 3.16, adjusted for differences in observation duration) than during the day of relocation (11.60 ± 1.01; $P<0.001$), whereas in stall-housed animals, no significant differences were found (Feeding Time: 7.59 ± 1.69, Day of Relocation: 6.96 ± 1.18; $P=0.26$).

Lesions

The post-relocation increase in lesion score was higher for group-housed sows (22.52 ± 2.31) than for stall-housed animals (1.98 ± 0.40; $P<0.001$), while the effect of parity on the increase in lesions tended towards significance ($P=0.08$). In group-housed animals the total increase in lesions was positively correlated with AGG ($P<0.001$), and to a lesser extent, with ACT ($P<0.01$), whereas in stall-housed animals the total increase was not correlated with either AGG ($P=0.24$) or ACT ($P=0.32$). Passive aggressive encounters (PAS) were not correlated with the total increase in lesions in either a group-housing ($P=0.23$) or stall-housing environment ($P=0.32$). When only considering lesions on the front part of the body, in group-housed sows the increase in lesions was positively correlated with AGG ($P<0.01$) and ACT ($P<0.05$) but not with PAS ($P=0.15$). However, in stall-housed animals, it tended to be positively correlated with AGG ($P=0.06$) and PAS ($P=0.06$) but not with ACT ($P=0.27$).

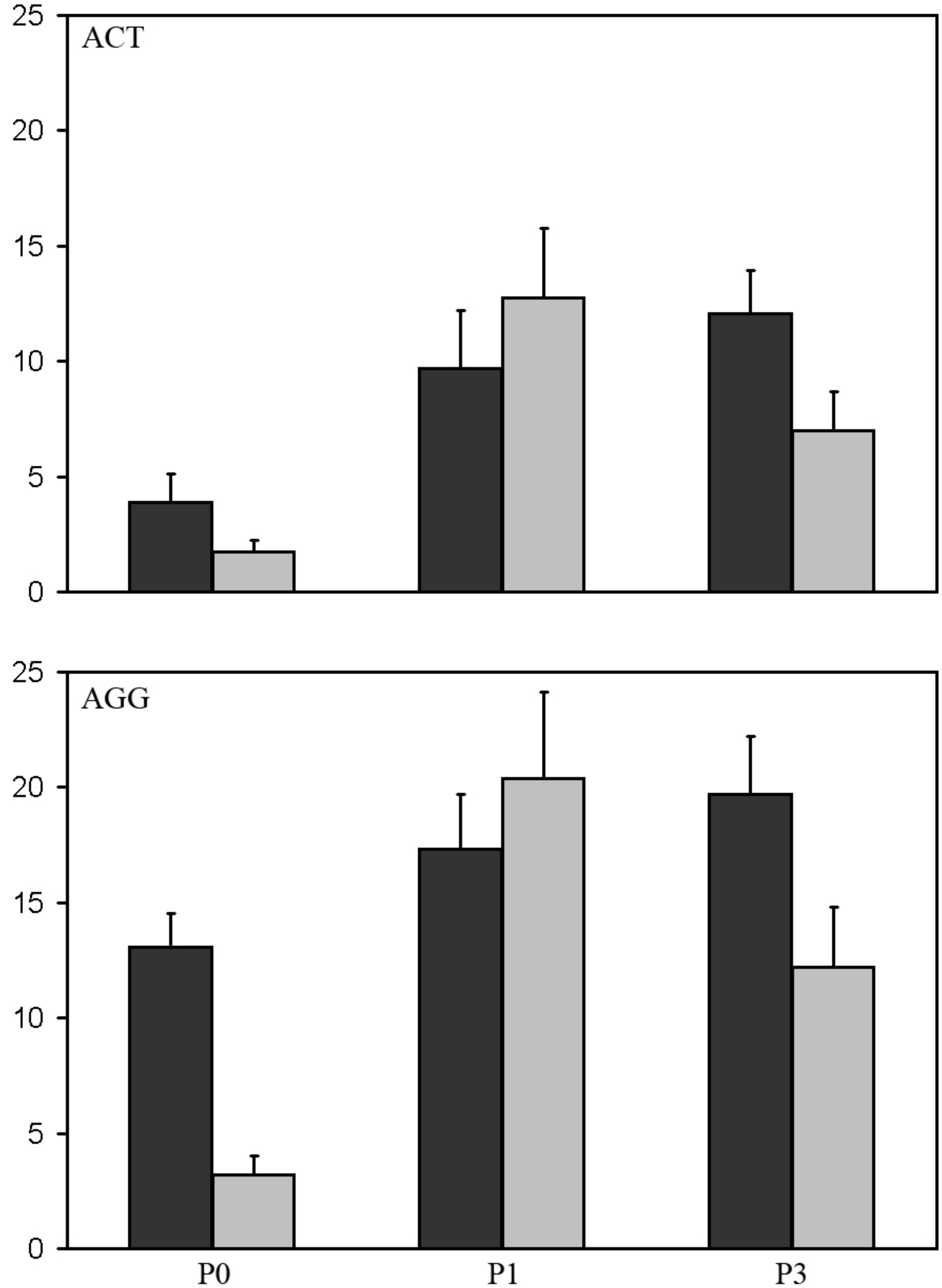

Figure 1. Effects of housing environment and parity on the mean number (± SEM) of active aggressive encounters (ACT) and total aggressive encounters (AGG) after relocation. P0, P1 and P3 indicate parity, dark bars indicate group-housed sows, light bars indicate stall-housed sows.

Cortisol Concentrations

Housing environment affected the average increase in cortisol concentration after relocation ($P<0.01$). Animals moved into a group-housing system showing a marked increase in salivary cortisol concentrations (1.21 ng/dl ± 0.12), while animals relocated to a novel stall showed a slight decrease in salivary cortisol concentrations (-0.05 ng/dl ± 0.02). Parity did not affect the change in cortisol concentrations after relocation (P=0.55).

The amplitude of the circadian rhythm in salivary cortisol concentrations differed between group-housed and stall-housed sows ($P<0.001$). Group-housed animals (2.16 ± 0.32) had greater cortisol amplitudes than did stall-housed animals (0.22 ± 0.02). Parity did not affect the amplitude (P=0.32).

Difference between pre- and post-relocation cortisol concentrations were not correlated with ACT, PAS or AGG, regardless of housing environment (Group housed sows: ACT, P=0.90, PAS, P=0.25 and AGG, P=0.51; Stall housed sows: ACT, P=0.85, PAS, P=0.54 and AGG, P=0.79), nor was it correlated with lesion score (Group housed sows, P=0.85; Stall housed sows, P=0.31).

Discussion

Lesion scoring was a good predictor of the number of aggressive encounters that the group housed sow experienced. Strategies to assess the effectiveness of management techniques to reduce aggression could take advantage of this association.

This study demonstrated that feeding time was the most important factor affecting the higher levels of aggression recorded in group-housed animals, when compared with sows housed in gestation stalls. Therefore, in order for the welfare of sows kept in groups to be maintained, better systems for delivery of food need to be developed. Floor feeding is an inexpensive alternative but it favors the onset of aggressive interactions. However, anecdotal evidence suggests that increasing the frequency of floor feeding (eg. 8 x daily) markedly reduces sow aggression. This suggestion remains to be critically assessed. Older sows are the ones involved in most of the aggressive interactions, both in individual and group housing. Studies designed to assess aggression in sows should balance the sows according to their parity. The differences recorded in the circadian salivary cortisol pattern of sows kept in groups and gestating crates is very intriguing and supports a previous report (Zanella et al. 1996). Sows kept in gestating crates had lower levels of salivary cortisol and showed smaller increases in cortisol levels in response to the relocation process than sows kept in groups. Interestingly, women subjected to abuse also did not have circadian cortisol profiles and were more likely to deliver prematurely (Holzman et al. 2002). However, any extrapolation of this observation to sows requires great caution since a muted circadian rhythm in stalled sows is not associated with reduced fertility. Indeed, the cortisol data generated in this study and in our Experiment 4 indicate no direct link between cortisol and sow fertility.

However, this does not exclude the possibility of an as yet undetermined link between the hypothalamic-pituitary-adrenal axis and reproductive performance. Future studies to understand the central mechanisms controlling the stress axis may help to explain the relationship between cortisol levels and chronic stress and possibly elucidate a link to fertility.

Lay Interpretation

These data demonstrate that group-housed sows fight more than individually housed sows and consequently exhibit more lesions. The group-housed sows had higher salivary cortisol concentrations suggesting a greater level of stress in these sows. However, of particular interest is the observation that aggression was greater during feeding than after mixing. This indicates that if producers move to a group housing of sows, particular attention must be focussed on feeding management.

Experiment 2 (objective 2)

Material & Methods

Animals and Treatments

A total of 937 mixed parity sows in 10 weekly breeding groups were either group housed in pens (n=462) or individually housed in gestation stalls (n=475). All sow management was as described for experiment 1. For 140 individually-housed and 330 group-housed sows ('observed sows'), backfat depths at the P2 position (65 mm off the mid-line at the last rib) were determined at 55-60 d of gestation, at farrowing, and at weaning using A-mode ultrasonography (Renco Leanmeater®). The total and live-born litter sizes were recorded for each observed sow. Additionally, the farm database was accessed to allow the determination of farrowing rates for all sows (observed and non-observed) in the 10 breeding groups.

Statistical Analysis

Data for treatment effect on farrowing rate were compared using Chi square. Data for treatment effects on sow backfat depths, litter sizes and wean-to-estrus intervals were examined by GLM ANOVA.

Results

There was no effect of housing management on farrowing rate (Table 2.1). A minor difference (1.2 mm) in backfat depth was evident at 50-d of gestation but differences were not evident at either farrowing or weaning (Table 2.1). Also, there was no indication that variation in backfat depth increased with group housing and feeding of sows. However, group housing of sows was associated with smaller litters, both total born (P=0.04) and born-alive (P=0.03). The subsequent wean-to-estrus interval was not affected by gestation housing management (Table 2.1).

Table 2.1. Effect of group or stall housing on sow performance (means ± SE)

	Stalls	Pens	P
Total number of sows	475	462	
Farrowing rate, %[1]	77.8±1.8	76.6±2.2	0.68
Number of sows observed	140	330	
50-d backfat, mm	18.9±0.4	17.7±0.4	0.04
Farrowing backfat, mm	18.6±0.5	19.3±0.3	0.24
Weaning backfat, mm	16.4±0.5	16.3±0.3	0.98
Total born	11.3±0.3	10.5±0.2	0.04
Live born	10.5±0.3	9.7±0.2	0.03
Wean-estrus interval, d	10.2±0.8	10.5±0.5	0.74

[1] Farrowing rate refers to all sows in the 10 breeding groups, ie. it includes those sows that were observed and those that were not observed for backfat changes.

Discussion

Within the limits of this study (ie. grouping for approximately the last 50 days of gestation), these data do not support the suggestion that group housing of sows during gestation increased absolute or variation in backfat depth. Therefore, based solely on backfat depth as a measure of variation in sow feed intake, group housing of pregnant sows appears to induce no adverse effects. However, although farrowing rate appeared unaffected by grouping at 50 days of gestation, the evident reduction in litter size at birth is potentially of economic significance. The etiology of this effect is not known but may involve an adverse effect of stress associated with aggression both at initial mixing and with daily feeding. Indeed, experiment 1 indicated that aggression at feeding was as marked as at mixing and remained evident even after the aggression associated with mixing was resolved. It has been suggested that sow fertility may suffer if stress is sufficiently prolonged (Turner et al. 2002), such as appears to be evident in the present study, although others noted no adverse effect on fertility of repeatedly mixing groups of pregnant gilts at 7-day intervals (Soede et al. 2002). If the stress of aggression was the proximate cause of the reduced litter size, it implies that grouping even at mid gestation can have adverse effects on fetal viability. Unfortunately, the present study only recorded live and stillborn pigs. If grouping of sows is associated with increased fetal mortality, future studies should include a closer inspection of litters for evidence of early mummies.

Although specific data were not recorded, the gestation manager observed that more sows were removed for lameness in the group pens. His estimate was that in a group of 60 sows grouped at 60-65 days of gestation usually 4 would be removed for lameness. When grouping was delayed to 85-90 days, no more than one would be removed. At the termination of the study, this anecdotal evidence was considered sufficient to justify the delaying of grouping of all sows until at least 90 days of gestation.

Lay Interpretation

The present study involved the group housing and feeding of sows during the second half of gestation. When using this approach there was no evidence of an increased variation in sow body condition. However, even when grouped this late, a reduced litter size was noted. Further, anecdotal evidence suggested that grouping of sows in mid gestation resulted in an increased incidence of lame sows. Taken together, and within the housing limitation of this study (semi-slatted concrete flooring with no additional bedding), this experiment does not support the group housing of pregnant sows.

Experiment 3 (objective 3)

Material & Methods

This study involved 1,584 sows in 2 commercial 3,000-sow commercial farrow-to-wean herds. In these herds, sows farrowed and lactated indoors in farrowing crates and were weaned into individual gestation stalls for estrus detection and breeding by artificial insemination. Semen was collected and processed in-house to provide insemination doses containing 3 x 10^9 sperm. All insemination doses within each breeding week were identical pooled semen. Sows were weaned on Tuesdays and on the second Friday after weaning, bred sows were formed into groups of approximately 50 and moved into 0.5-acre outdoor paddocks. Pregnancy status was determined at 25 to 30 days after insemination and pregnant sows were moved to a 7-acre paddock for the remainder of gestation and any open sows moved back to the breeding barn. The interval from last insemination to sow mixing was 1 to 5 days. Alternate sow groups included a team of 3 mature boars that remained with the sows for 14-days before being moved to a new sow group.

During gestation sows were allowed ad libitum access to feed for an 8-hour period every third day. Pregnant sows remained with their group until re-housed in the farrowing rooms at 110 days of gestation. The effect of boar presence on sow fertility was assessed on the basis of farrowing rate to first service and subsequent total-born litter size.

Statistical Analysis

Data for effect of boar presence and mating-to-mixing interval (MMI) on farrowing rate and litter size for each breeding week were compared by GLM ANOVA.

Results

There was an effect ($P<0.002$) of farm on farrowing rate (80.5 vs. 70.9% for farms 1 and 2, respectively), but there was no effect of boar exposure (76.1 vs. 77.8% for control and boar exposed, respectively). Similarly, farrowing rate was not influenced by wean-to-estrus interval (6.3±0.2 days, for pregnant and non-pregnant sows) or MMI (Table 3.1). The mean MMI was 3.8 days for both pregnant and non-pregnant sows.

Litter size was influenced by farm (11.7±0.11 vs. 11.2±0.16 for farms 1 and 2, respectively; $P=0.023$) and by boar exposure (11.4±0.12 vs. 11.8±0.14, for control and boar exposed, respectively; $P=0.035$), but there was no evident interaction between farm and boar exposure. There was a tendency ($P=0.1$) toward smaller litter size when MMI was greater than 1 (Table 3.1).

Table 3.1. Effect of mating-to-mixing interval and boar exposure on sow fertility

	Farrowing rate, %	Litter size (total born)
Control (all sows)	76.1	11.4±0.12a
Boar exposed (all sows)	77.8	11.8±0.14b
Mating-mixing interval		
1 day	74.2	12.3±0.4 (66)*
2 days	73.5	11.2±0.3 (115)
3 days	72.0	11.0±0.3 (132)
4 days	78.5	11.6±0.2 (340)
5 days	78.1	11.7±0.1 (527)

a,b; means followed by different letters differ ($P<0.05$)

*, numbers in parenthesis are number of sows

Discussion

The present data indicate that, under the conditions of this study, the ability to maintain pregnancy was not affected by the inclusion of boars in the sow groups. This may be a reflection of the extensive area of the outdoor paddocks allowing ready escape for subordinate sows, with a consequent reduction of aggression-associated stress. However, a positive effect of boar presence on subsequent litter size was evident which suggests some beneficial effect. The potential effect of boar presence for reduction of aggression would likely have been evident at feeding, where all sows and boars would have had to congregate on an intermittent basis. However, this study was purely an examination of sow performance and behavioral measurements were not made. The apparent lack of effect of boar exposure on farrowing rate may also have been due to a masking effect of a seasonal impact on sow fertility. This study was conducted during June to November in outdoor sows with a known herd history of seasonal infertility. Although speculative, it is possible that boar exposure have had a greater effect outside of the period of seasonal infertility. It is interesting that, as described for experiment 4 below, boar exposure had no beneficial effect under confined conditions, which suggests the possibility of an interaction between housing density and boar exposure on sow fertility. However, this possibility was not addressed in the present study.

Lay Interpretation

The present study involved the group housing of sows into outdoor paddocks at 1 to 5 days after artificial insemination. Alternate sow groups included a team of 3 boars whose function was to reduce sow aggression and thus levels of stress. We noted that boar exposure had no effect on farrowing rate but did increase litter size by 0.4 pigs. It is possible that chronic stress associated with initial grouping and subsequent intermittent group feeding was detrimental to embryo survival. While not sufficiently bad to terminate the pregnancy, it was sufficient to kill some embryos. These data suggest that if strange sows are to be mixed, potential adverse effects on fertility may be reduced if boars are included within the groups.

Experiment 4 (objectives 3, 4, and 5)

Material & Methods

Animal Management

This study used 309 mixed parity Yorkshire x Landrace sows housed at the University of Guelph swine facility to examine the effect of gestational age at mixing and exposure to boars on sow behavior and fertility. Sows were weaned into groups of 3-4 and exposed to a mature boar to facilitate the onset and detection of estrus. Sows were artificially inseminated with 3×10^9 sperm at estrus detection and again at 24-hour intervals while still in good standing estrus. Following mating, sows were housed in individual gestation stalls until they were either moved to a new stall in the gestation barn or mixed into groups of 15 sows. Space allotment for each group of 15 sows was 25 ft^2 per sow. Sows were fed once daily (~2.5kg/sow/day) between 08:00 and 08:30 h. For the group-housed sows, feed was distributed onto two separate areas of the floor by a drop feeding system.

Effect of Boar Presence on Sow Aggression

The experimental design was an incomplete block. There were 3 levels of boar presence: 1) Boar in pen with sows (PHYSICAL), 2) Boar housed opposite to sows (FENCELINE) and 3) No boar present in the room (CONTROL). Five groups of 15 multiparous sows were subjected to each treatment.

Five intact mature boars were chosen from the boar pool based on age, weight and body condition to ensure that they were heavier and larger than the sows. Each individual boar was used on five occasions and balanced across boar treatment so that he was mixed into one sow group and housed adjacent to a sow group. The boars were introduced into the pen 15-min before the sows were mixed (ca. 10:00 h) and then removed at approximately 10:00 h on day 6 post-mixing. Square footage was not adjusted between the 'boar housed with sows' and the other treatments. All pens were power-washed with a commercial washer before any new group was introduced.

Superficial skin scratches were assessed, separately for each shoulder, on four separate occasions: 24h pre-mixing, 24h post-mixing as well as 24h before and after removal of the boar/cleaning of the pen. Control groups were treated equally. A scoring system for the number of skin scratches was developed following methods described in Hodgkiss et al. (1998) and de Koning (1984). Qualitative features of the scratches (ie. age) were not documented. A score of 0 was assigned when no scratches were evident on a shoulder; a 1 was assigned when there were less than 5 scratches observed on a shoulder; a 2 was assigned when 5-10 scratches were visible on a shoulder; and a score of 3 indicated more than 10 scratches on a shoulder. The sum of both shoulders was calculated and re-categorized as NONE (score = 0), MILD (score = 1 or 2), MODERATE (score 3 or 4) and MULTIPLE (score 5 or 6). Hence, the minimum injury score for an individual sow was zero, and the maximum was six. Deep, purulent wounds were never observed throughout this study.

Groups of sows were digitally recorded using a Digital Recording System (Kodicom, Toronto, ON). Groups were continuously recorded from the time they were introduced into the pen as a group until 48hrs post-mixing, and then for 24hrs before and 48hrs after removal of the boar/cleaning of the pen. The control treatments followed the same video recording schedule. Three cameras were positioned on the ceiling above each pen. Sows were individually identified with the use of livestock spray in order to facilitate data collection.

Behavioral data were collected from the digital recordings. The frequency and duration of fights were collected for each of the time periods (0-24 & 25-48 hrs post-mixing, 0-24hrs pre-removal and 0-24 & 25-48 hrs post-removal). Data was further separated into feeding and non-feeding periods. Feeding periods were defined as beginning when the food was dropped and ending when more than 50% of sows were no longer engaged in oral/nasal activity directed towards the floor. The control treatments followed the same behaviour-sampling schedule. Due to differing total time sampled per day, the frequencies and duration of fights were standardized on a per group per hour basis.

To determine the effects of boar presence at mixing on the stress response of sows, saliva was collected at either 0600-0700 h (AM) or 1600-1700 h (PM) at the following times: the day before mixing (AM and PM), 6 h post-mixing (PM), the day following mixing (AM and PM). Saliva samples were also collected the day before boar removal (AM and PM), 6 h after boar removal (PM) and the day following boar removal (AM and PM).

Effect of Gestational Age at Mixing on Fertility

Each group of 15 multiparous unfamiliar sows comprised 3 sows mixed at each of 2, 7, 14, 21 and 28 days from breeding. Attempts were made to balance treatments for parity. The sows were kept in the group housing facility for five weeks, after which they were moved to gestation stalls until farrowing. Five sows (one from each breeding period) were moved to novel stalls in the breeding barn at times that corresponded to the mixing of groups. Sows at 28 or more days at mixing (or moving) had not shown signs of returning to estrus and/or were confirmed pregnant using-real time ultrasonography.

All animals were either mixed or relocated to stalls at 10:00 h, to ensure that they had eaten. Sows were ultrasonically monitored for pregnancy on a weekly basis. In order to maintain the group social structure, any sow that came into heat during the trial was not removed. Reproductive data recorded were total and live-born litter size and subsequent farrowing rate.

Statistical Analysis

The effects of day of pregnancy and boar exposure treatment on farrowing rate were examined using Chi square. Effects of boar exposure treatment and day of pregnancy on litter size were subjected to GLM ANOVA. Effects of boar exposure treatment on scratch scores, behaviour and salivary cortisol concentrations were analyzed using PROC MIXED with group as the experimental unit and boar and block as random effects. Means were compared using a Tukey test.

Results

Groups of sows exposed to the PHYSICAL treatment had significantly lower mean scratch scores, 24h post-mixing and 24hrs pre-removal, when compared to the CONTROL ($P < 0.05$). Furthermore, the PHYSICAL treatment tended to or did significantly reduce the mean scratch score 24hrs pre-removal ($P < 0.1$) and 24hrs post-removal ($P < 0.05$) compared to the FENCELINE treatment (Table 4.1).

Salivary cortisol concentrations were elevated in all treatment groups following mixing, and values were higher for sows in PHYSICAL contact with the boar compared to those with FENCELINE contact (Table 4.2). The mean (± SEM) frequencies and durations of fights occurring during non-feeding and feeding times during the first two days after mixing are given in Tables 4.3 and 4.4.

Table 4.1: The effect of boar exposure on the mean (± SEM; N=5) scratch score assessed pre- and post-mixing and removal periods. Periods were analyzed separately. Pre-mixing value used as a covariate when analyzing all periods

Treatment	**Pre-Mixing**	**Post-Mixing**	**Pre-Removal**	**Post-Removal**
Control	1.04 ± 0.18	2.56 ± 0.26 [a]	2.59 ± 0.30[ac]	2.43 ± 0.32
Fenceline	0.95 ± 0.26	2.41 ± 0.21	2.45 ± 0.18[a]	2.57 ± 0.18[a]
Physical	0.87 ± 0.12	2.05 ± 0.13 [b]	2.00 ± 0.10[bd]	1.97 ± 0.08[b]

a,b; means within in column followed by different letters differ (P<0.05)

c,d; means within a column followed by different letters differ (P<0.10)

Table 4.2. The effect of boar presence on the mean (± SEM; N=5) morning and afternoon salivary cortisol concentrations (ng/mL) pre- and post-mixing periods. Periods were analyzed separately. Pre-mixing value used as covariate for all periods.

Treatment	**AM**		**PM**	
	Pre-Mixing	**Post-Mixing***	**Pre-Mixing***	**Post-Mixing***
Control	0.17 ± 0.02	0.31 ± 0.05	0.16 ± 0.04	0.26 ± 0.03
Fenceline	0.24 ± 0.05	0.30 ± 0.04[c]	0.20 ± 0.05	0.19 ± 0.04[a]
Physical	0.17 ± 0.05	0.49 ± 0.15[d]	0.17 ± 0.05	0.41 ± 0.12[b]

* The pre-mixing AM value was used as a covariate when analyzing these variables.

a,b; means within in column followed by different letters differ (P<0.05)

c,d; means within a column followed by different letters differ (P<0.10)

Table 4.3: The effect of boar exposure on the mean (± SEM; N=5) frequency of fights occurring per group per hour during non-feeding and feeding periods.

	Non-Feeding	**Feeding**
0-24 hrs post-mixing		
Control	1.23 ± 0.07	2.44 ± 1.24
Fenceline	0.89 ± 0.13	2.99 ± 1.32
Physical	1.27 ± 0.27	5.98 ± 1.64
25-48 hrs post-mixing†		
Control	0.37 ± 0.07	1.36 ± 0.61[ab]
Fenceline	0.46 ± 0.12	2.45 ± 0.51[a]
Physical	0.38 ± 0.12	0.27 ± 0.27 [b]
0-24 hrs pre-removal*		
Control	0.18 ± 0.07[a]	0
Fenceline	0.01 ± 0.01[b]	0.27 ± 0.27
Physical	0.07 ± 0.02[ab]	0.27 ± 0.27
0-24 hrs post-removal*		
Control	0.02 ± 0.02[a]	0.27 ± 0.27
Fenceline	0.07 ± 0.04[ab]	0
Physical	0.13 ± 0.03[b]	0
25-48 hrs post-removal*		
Control	0.04 ± 0.03	0.82 ± 0.54
Fenceline	0.07 ± 0.04	0
Physical	0.04 ± 0.01	0

†Non-feeding value transformed using a reciprocal transformation

*Feeding periods not analyzed due to rare event of fights.

a,b; means within in column followed by different letters differ (P<0.05)

c,d; means within a column followed by different letters differ (P<0.10)

Table 4.4: The effect of boar exposure on the mean (± SEM; N=5) duration of fights occurring per group during non-feeding and feeding periods.

	Non-Feeding	**Feeding**

0-24 hrs post-mixing		
Control	61.7 ± 19.0	14.0 ± 6.9
Fenceline	35.4 ± 4.3	43.7 ± 25.3
Physical	38.1 ± 7.2	30.0 ± 4.6
25-48 hrs post-mixing		
Control	58.3 ± 15.5	31.70 ± 16.8
Fenceline	89.6 ± 25.8	59.9 ± 17.1
Physical	47.8 ± 8.7	21.0 ± 21.0
0-24 hrs pre-removal		
Control	23.2 ± 11.4	0
Fenceline	54.6 ± 54.6	3.8 ± 3.8
Physical	8.8 ± 2.4	44.6 ± 44.6
0-24 hrs post-removal†		
Control	2.1 ± 2.1	6.6 ± 6.6
Fenceline	9.8 ± 6.0	0
Physical	30.7 ± 13.8	0
25-48 hrs post-removal		
Control	49.4 ± 30.3	88.1 ± 86.4
Fenceline	40.3 ± 22.0	0
Physical	15.6 ± 6.3	0

There was no effect (P>0.5) of housing management or boar exposure treatment on total born and live-born litter size or on farrowing rates (Tables 4.6). Similarly, there was no effect (P>0.5) of day of pregnancy on either total born or live-born litter size (Tables 4.7). However, within the group-housed sows, farrowing rate was lower (P=0.05) in sows mixed at 14 days than in those mixed at 2 days, with all other days being intermediate (Table 4.7). Farrowing rates for sows individually housed at different days of pregnancy were combined because sow numbers on each day were inadequate for meaningful interpretation. The farrowing rate for the individually housed sows was not different from any other group (Table 4.6).

Table 4.6. Effect of boar exposure on sow fertility.

Treatment	Farrowing[1]	Litter size (total)	Litter size (live)
Stalls	79.7	11.65±0.52[2]	10.42±0.43
Control[3]	60/75 (80.0)	10.93±0.45	10.00±0.38
Fenceline[4]	70/90 (77.8)	11.80±0.42	10.51±0.35
Physical[5]	68/90 (75.6)	11.53±0.43	10.32±0.36

[1] Numbers in brackets are farrowing rates (%)

[2] Mean ± SEM

[3] Grouped-sows, no boar contact

[4] Grouped-sows, fenceline boar contact

[5] Grouped-sows, boars housed with the sows

Table 4.7. Effect of gestational age and boar exposure on the fertility of group-housed sows.

Pregnancy day	Farrowing[1]	Litter size (total)	Litter size (live)
2 d	43/50 (86.0)a	11.14±0.54	10.28±0.44
7 d	40/49 (81.6)	11.18±0.56	10.00±0.47
14 d	37/53 (69.8)b	11.89±0.58	10.46±0.47
21 d	40/53 (75.5)	11.78±0.56	10.65±0.46
28 d	38/50 (76.0)	11.29±0.57	10.03±0.47

[1] Numbers in brackets are farrowing rates (%).

ab, values followed by different letters differ, P=0.05

Discussion

In a group system, the first few days post-mixing are the most critical in terms of sow welfare. Newly mixed sows typically engage in aggressive interactions in order to establish a social hierarchy (Meese and Ewbank 1973; Arey and Edwards 1998). Altercations between sows during this period can lead to injury, mainly due to biting directed towards the front of the body (McGlone 1985). Examination of shoulder injuries can provide information about the state of a single animal as well as that of the herd (Leeb et al. 2001). Excessive physical injuries generally indicate inadequacies in the physical environment and are indicators of poor welfare (de Koning 1984; Dawkins 1988). The numbers of lesions are correlated with the incidence of aggressive interactions that occur within the few hours post-mixing (Barnett et al. 1996). The incidence and/or duration of aggressive encounters between sows may be reduced by boar presence. Previous studies have found that the physical presence of a boar reduces the frequency of aggressive behavior among groups of weaned sows, ovariectomized pigs and slaughter weight pigs (Docking et al. 1999; Barnett et al. 1993; Grandin and Bruning 1992). Luescher et al. (1990) also reported that the presence of a boar tends to reduce aggressive behavior among groups of gilts. Our findings indicate that overall the presence of a boar does not seem to reduce the frequency or duration of fights among sows. Although the mean scratch score was generally lower in the PHYSICAL treatment compared to the other treatments throughout the various periods. It is not clear what relationship exists between the frequencies or duration of fights and the scratch scores. Further analysis of the data is required.

Mixing unfamiliar animals together can result in social stress, which can lead to an acute stress response (Otten et al. 1997; Parrott and Misson 1989). Social interactions between female and boars have also been shown to increase their hypothalamic-pituitary adrenal response. Non-estrus sows and pre-pubertal gilts show elevated levels of cortisol when directly exposed to a boar (Jongman 1993; Pearce and Hughes 1987). In our study salivary cortisol concentrations were elevated in all treatment groups following mixing, although the CONTROL and PHYSICAL treatments were numerically but not significantly different. This lack of statistical significance is potentially due to large variation that occurred within and between groups of sows. In accordance with the literature, the levels of cortisol were higher in response to full boar exposure than fenceline contact.

The present data suggest that under the conditions of this experiment, there was no effect of housing management on litter size. Previous reports have indicated varied responses of litter size to housing management. A reduction in litter size was associated with group housing (Bokma 1990; Fisker 1995; Hansen 2000) and mixing of strange sows (te Brake and Bressers 1990) has been documented. However, others report no effect on embryo survival or litter size (England and Spurr 1969; Tsuma et al. 1996; Olsson and Svendsen 1997; Soede et al. 2002; Bates et al. 2003). These literature data suggest that other factors may interact with the effect of grouping to impact (or not) subsequent litter size, resulting in no clear statement regarding the effect of housing management on litter size. Similarly, the presence of a boar did not impact litter size. However, given that the level of aggression in the present study was not sufficient to affect embryo/fetal viability and that the presumed effect of the boar is to reduce aggression, the lack of effect of the boar was to be expected.

The data from this experiment indicated no effect of housing management or boar exposure on farrowing rates. In concert with literature data concerning litter size, reported effects of group housing of sows on pregnancy or farrowing rates have been inconsistent. No effect was observed in some studies (England and Spurr 1969; Soede et al. 2002) while others reported reductions (Bokma 1990; Nicholson et al. 1993; Olsson and Svendsen 1997) or even an improvement (Bates et al. 2003). As indicated above, the literature data suggest that other factors likely interact with the effect of grouping to impact (or not) the ability to conceive and maintain a pregnancy to term. A possible interactive factor is the stage of pregnancy when mixed. The present data indicate a lower farrowing rate for sows mixed at 14-days compared to those mixed at 2-days of pregnancy. Day 14 is close to the time of the first signal for maternal recognition of pregnancy and the start of placental attachment. A physiological perturbation at this time has the potential to interfere with the successful establishment of pregnancy. Interestingly, te Brake and Bressers (1990) noted a reduced litter size when sows were mixed at 10 days compared to those mixed at latter times. From a clinical standpoint, it would be invaluable to know the pattern of returns to estrus in sows failing to maintain pregnancy but this information has not been provided. If future studies provide this additional data, it would be possible to determine more accurately when the pregnancy was lost. This, in turn, would provide insight as to the potential mechanisms involved.

Lay Interpretation

The data from this experiment suggests that the mixing of strange sows into groups can be done without adversely affecting fertility. The lack of overall effect on litter size and farrowing rate provides no impetus to support or refute arguments concerning group housing. However, we did note a reduction in farrowing rate when sows were grouped at 14 days after insemination. This suggests that there is a period during early pregnancy when sows are more sensitive to the stresses associated with mixing. Based on the present data and that in the literature, this period of sensitivity will be at a minimum from 10 to 14 days after mating. However, more work will be needed to accurately delineate the sensitive period. There is no clear advantage of boar presence on reducing aggression and stress among newly mixed bred sows.

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