Effects of group housing after weaning on sow welfare and sexual behaviour

Rault, Jean-Loup; Hemsworth, Paul; Morrison, Rebecca; Tilbrook, Alan; Hansen, Christian Fink

Publication date:
2014

Document version
Early version, also known as pre-print

Citation for published version (APA):
Rault, J-L., Hemsworth, P., Morrison, R., Tilbrook, A., & Hansen, C. F. (2014). *Effects of group housing after weaning on sow welfare and sexual behaviour*. Co-operative Research Centre for High Integrity Australian Pork.

Effects of group housing after weaning on sow welfare and sexual behaviour

1C-111

Report prepared for the Co-operative Research Centre for High Integrity Australian Pork

By

Jean-Loup Rault[1], Paul Hemsworth[1], Rebecca Morrison[2], Alan Tilbrook[3] and Christian Hansen[4]

[1]Alice Hoy building 162, room 003, Animal Welfare Science Centre, School of Land and Environment, University of Melbourne, Parkville, VIC 3010
[2]Rivalea Australia
[3]South Australia Research and Development Institute (SARDI)
[4]University of Copenhagen, Denmark

March 2014

An Australian Government Initiative

Established and supported under the Australian Government's Cooperative Research Centres Program

Executive Summary

There is increasing pressure from some sectors of the community to eliminate the use of sow mating stalls post-weaning. Anecdotal evidence from the pork industry in Australia and Europe suggests that weaning sows in groups may reduce farrowing rate and litter size. This industry perception highlights the need to examine the effects of weaning sows in groups in controlled experiments, and its effects on stress, aggression, sexual behaviour and reproductive performance. This will assist the industry in developing a group housing system that does not compromise welfare and reproduction and that is sustainable for industry if sow stalls are to be eliminated for the entire production cycle.

This project compared the effects of grouping sows after weaning or after insemination on sexual behaviour, aggression, injuries, stress and reproductive performance. On the day of weaning (day 1), 360 sows were either housed in groups of 10 sows at 4.4 m^2 per sow (18 groups) or kept in individual stalls (18 groups). Within two days after insemination, a cohort of sows were moved to groups of 7 sows at 2.1 m^2 per sow, grouping those sows from stalls and keeping familiar groups of sows that had been grouped at weaning.

Group-weaned sows showed no difference in the wean to first insemination interval within 5 days of weaning, the onset of oestrus or the length of oestrus compared to stall-housed sows. However, 7% less group-weaned sows were inseminated within 5 days of weaning and the sexual receptivity test revealed that group-weaned sows were less receptive than stall-housed sows, showing less spontaneous standing during boar exposure and partly compensating by showing a greater response to the back-pressure test in presence of the boar. Group-weaned sows also showed greater variability in retention rate at d 7, with 3 out of 18 pens retaining only 5 out of 10 sows. Mixing after weaning resulted in higher levels of stress than mixing after insemination, based on cortisol concentration and aggression, and group-weaned sows lost in average 2.8 kg of body weight while the weight of stall-housed sows remained stable during this first week post-weaning. Sexual behaviour directed to others was delivered predominantly by dominant sows, and mostly consisted of ano-genital sniffing while flank nosing and mounting behaviours increased on days 5 and 6. Frequency of sexual behaviour initiated by group-weaned sows tended to correlate with weight loss and sexual behaviour received correlated with cortisol concentration, suggesting that sexual behaviour between sows was linked to the stress and stress effects of mixing sows after weaning. No treatment effects were found on reproductive variables (conception rate, return rate, farrowing rate, total piglets, born and born alive, and culling rate), but a larger sample size is required to sufficient power to test these effects.

Sows housed in groups at weaning experienced higher stress than sows housed in individual stalls at weaning and housed in groups after insemination. Although group-weaned and stall-housed sows performed equally well overall, the greater variability in performance such as insemination rate between pens of weaned sows will reduce the predictability of this system. A possible lower sexual receptivity also emphasizes the importance of appropriate and sensitive oestrus detection protocols in group-weaning systems. Research on a larger sample size is needed to assess whether group-weaning affects farrowing performance, particularly between-batch variability and therefore could result in under-use of housing facilities and economic losses for pork producers. This study was performed using best practices; therefore results could be sub-optimal in other settings (e.g. mixed parity, dynamic grouping, no sow protection at feeding, restricted feed post-weaning, etc.). More comprehensive research is needed to reduce variability, manage aggression and optimise oestrus detection in group-housed weaning systems.

Table of Contents

1. Introduction

Confinement of sows during gestation have been heavily scrutinised by animal welfare groups. The Australian pork industry has voted to pursue the voluntary phasing out of gestation stalls by 2017. A critical time for sow reproduction and productivity is the interval between weaning and mating, and the subsequent reproductive success. Sows seem particularly sensitive to stressors during that period. Therefore, the Australian pork industry has elected to continue using mating stalls between weaning and for a maximum of five days after insemination. However, there is increasing pressure from animal welfare groups and retailers to house sows directly into group housing systems after weaning based on perception that sow welfare may be improved. Nevertheless, factors such as the social environment and its effect on welfare and reproductive performance require further investigation.

Mixing sows directly after weaning could affect the sexual behaviour of the sows, hence their return to oestrus and reproductive success. Little is known about the impact of stress and cortisol on sexual behaviour in the female. It is generally agreed that stress can impair reproduction: Turner et al. (2005) in a review of the literature concluded that prolonged stress and sustained elevation of cortisol can disrupt reproductive processes in female pigs. Hence, mixing shortly after insemination may cause a stress response and affect fertilization and implantation success. The general consensus in the scientific literature is that most embryonic death occurs within the first 30 days of gestation, as this is a sensitive time when a range of environmental, social, genetic, nutritional, hormonal and biochemical factors are interacting with each other, all having significant influences on conception rate and ultimate litter size (Ashworth and Pickard, 1998).

This project examined the effects of grouping sows after weaning or after insemination on sow welfare, sexual behaviour, stress and reproductive performance. This project was truly innovative by investigating the effects of the housing system (group vs. stall) around oestrus and insemination on sexual behaviour. Furthermore, the effects of the housing system around oestrus and insemination on aggression, injuries, stress and reproductive performance have received surprisingly little research attention. This project aimed at determining the impact of housing strategies at weaning on sow welfare and performance and consequently the need for more thorough investigation of temporal effects and mechanisms.

2. Methodology

2.1. *Animal selection and 1 week post-weaning treatments*

This experiment was conducted at a large commercial piggery in New South Wales, Australia between September 2013 and January 2014. The project was approved by the Rivalea Animal Ethics Committee in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes. A choice was made to use industry best practices by offering 4.4 m^2 per sow in the mixing pen, keeping sows in static groups of same parities, with *ad libitum* feed, full length body stalls and standardising boar exposure for 30 s daily while locked in the feeding stalls.

On the day of weaning ('day 1'), 360 Landrace × Large White sows were allocated by parity (1 to 6) and estimated body weight to one of two treatments:

'Group-weaned' treatment or 'Stall' treatment in groups of 10 sows over 3 replicates, one week apart. We obtained 18 groups per treatment: 6 groups of parity 1 sows and 3 groups each of parities 3, 4, 5 and 6. Sows that were severely lame were excluded, based on a gait score of 2 or 3 (see section 2.4.1. below). Sows were individually marked with livestock spray paint according to their allocated treatment, were weaned and then moved to their new accommodation around 0940h. For the 'Group-weaned' treatment, 10 sows, unfamiliar with each other, were mixed into a pen with 4.4 m^2 per sow. Pen design characteristics consisted of 6.3 m x 7 m floor space (including feeding stall) with 10 full-length body feeding stalls on the front side of the pen, a 1.5 m strip of slatted floor and the rest as concrete floor, and 2 nipple drinkers on each side of the pen. Sows were wet fed in the trough placed in front of the stalls 2.7 kg per sow of a dry commercial pelleted diet 3 times a day (approximately 0730, 1130 and 1430h) for a total of 8.1 kg per sow daily, hence *ad libitum*, from day 2 to day 7 (DE: 13 MJ/kg DM, CP: 13.3%, Lysine content: 0.5%).

Group-weaned sows were manually locked in the stalls by placing a back-door at the first feeding of the day to allow for the subsequent mating check. Sows were not locked in at the other two feeding times. The floor area of the pens was cleaned between each replicate. For the 'Stall' treatment, sows were individually housed in 2.2 m × 0.6 m stalls equipped with a nipple drinker and horizontal bars, and managed in groups of 10 sows (10 adjacent stalls) to control for the number and management of sows in each group-weaned pen. Stalled sows were located across the alleyway facing the group-weaned pens stalls, and fed the same diet delivered in an identical manner to the Group-weaned treatment.

2.2. *Boar exposure, oestrus detection and artificial insemination*

On day 2, a two year-old Large White × Landrace boar was let to roam freely down the hallway for 1.5 h in the morning with all sows locked in the stalls at feeding to control for identical boar fence line stimulation between treatments. From day 3 to day 7, all sows were locked in the stalls at the first feeding and 2 boars were rolled down the hallway once a day around 0800h using rolling carts, with a pause of 30 s in front of each sow. The alleyway side of presentation of the two boars (group-weaned treatment side or stall treatment side) was reversed each day in order to balance for boar effect. Oestrus detection was done by 2 stockpeople whose identity could vary within and between replicates.

Sexual receptivity was scored using a system specifically developed for this study. This sexual receptivity scoring system ranked from 0 to 2: a score of 2 was attributed if the sow showed a spontaneous standing response (immobile stance, arched back and cocked ears) upon presentation of the trolley boar. Thereafter, the stockperson performed a 'back pressure test' on each sow by pressing with both hands on the back of the sow (Signoret and Du Mesnil du Buisson, 1961), and a score of 1 was attributed if the sow showed a standing response (immobile stance, arched back and cocked ears) to the back-pressure test for at least 10 s, with the stockperson counting up to 10 in their head for practicality purposes. A score of 0 was attributed if the sow did not show a spontaneous standing response upon presentation of the trolley boar or a standing response to the back-pressure test for at least 10 s. Only sows that scored 1 or 2 were artificially inseminated, using commercial pooled semen. All sows of a group remained locked in the stall for the duration of oestrus detection and insemination. An attempt was made to keep sows locked in their stalls for 2 h after insemination, as this has been suggested to increase farrowing rate, especially for parities 2 and 3 sows (Fisker, 2003). Following the first insemination, sows were subsequently inseminated the following day, irrespective of their receptivity score. Receptivity scores were still recorded for each individual sow from day 3 to day 7. No boar was present in that shed other than the boars housed 20 m away from experimental sows.

2.3. *Post-mating period*

Six days after weaning ('day 7'), 7 sows out of 10 were selected from each group (group-weaned pen or group of 10 stalls) with the inclusion criterion of having been inseminated twice by day 7 (in other words, a first insemination within 5 days after weaning) and the exclusion criterion of lame sows with a gait score of 2 or 3 (see section 2.4.1. below). If more than 7 sows had been inseminated twice, focal sows for blood sampling and sows having received their second insemination within 24 h prior to mixing were selected in priority and remaining excess sows discarded from the rest of the experiment at random. If less than 7 sows had been inseminated twice, the maximum number of sows inseminated twice was kept but no other sows were added to maintain groups of familiar sows. The 7 sows kept in each group were moved to a different building in the morning (Replicate 1: 0950h, Replicate 2: 1030h, Replicate 3: 1015h), 50 m away, in 5.03 m x 3.05 m pen with 2.1 m^2 per sow including shoulder feeding stalls. Groups originating from group-weaned treatment or stall treatment were alternated within rows of 12 pens. Pen design characteristics consisted of 10 shoulder stalls with 5 shoulder feeding stalls on either side of the pen, with a third of the area as slatted-floor and the rest as concrete floor and two nipple drinkers. Sows were wet fed in the troughs in the shoulder stalls on either side of the pen 2.7 kg per sow once daily around 0700 h from day 8. After pregnancy check 5 weeks post-insemination, the ration was reduced to 2.4 kg per sow. The floor area of the pens was cleaned between each replicate. Sows remained in these pens and in their original groups until approximately day 110 of gestation when they were moved to individual farrowing crates. The remaining sows went "off trial" and were either mixed with unfamiliar sows in the group pens specified above or if not mated were placed in mating stalls until their next oestrus.

2.4. *Measurements*

2.4.1. Weight and gait score

All sows were individually weighed at weaning on day 1 and the 7 sows from each group that remained in the post-mating period were weighed again on day 7. After weighing, sows were gait scored when walking to their new pen to assess the incidence of lameness. Gait score ranged from 0 to 3 scored visually by a single observer in all replicates with 0, Normal gait; 1, Irregular gait indicated by a visible degree of difficulty in walking, but still using all four legs and a swagger of caudal body while walking, shortened stride ; 2, Severely lame indicated by a visible reluctance to bear weight on the affected limb; or 3, Non-weight bearing indicated by no weight bearing on affected limb or total recumbency.

2.4.2. Skin lesions

On days 2 and 8, the following day after weaning and post-mating mixing respectively, each sow was individually assessed for skin lesions by one of three trained persons at approximately 0900h, as described by Karlen et al. (2007). Skin injuries were categorized into fresh injuries (scratches, abrasions, cuts, and abscesses), or partially healed or old injuries. Each side of the sow's body was divided into 21 areas for injury data collection (see Karlen et al., 2007). The number and the type of skin injuries were recorded, and, from these records, the number of both fresh and total injuries (fresh and old injuries) were collated for each sow on each observation day.

2.4.3. **Blood sampling**

On day 2, blood samples were collected via jugular venipuncture from 3 focal randomly chosen sows within each group around 1200h. Blood samples were collected within 2 min of restraint by snaring. The procedure was repeated on day 8 with blood sample collection on the same 3 focal sows from each pen if these remained in the group post-mating. If a focal sow had been discarded, a new focal sow was randomly chosen for day 8. Each 2 mL blood sample was collected in lithium heparin tubes (10-mL lithium-heparinized tubes; BD Vacutainer) and subsequently stored on ice before being centrifugated for 10 min at 1,912 × g at 4°C and transfer to microtubes for long-term storage at -20°C.

2.4.4. **Pregnancy and farrowing**

Regular checks for return to oestrus were conducted daily from 3 weeks after insemination, as well as a pregnancy test using ultrasonography 5 weeks after insemination. Sows that returned to oestrus, those that tested negative at the pregnancy test, and those with injury or in poor health were removed from treatment pens, and not replaced in the groups by other sows. However, the data from the 360 sows that started the experiment were included in the data analysis for pregnancy and farrowing rate. The total number of piglets born, and the number of piglets born alive, stillborn or as mummies were recorded.

2.4.5. **Behavioural analyses**

Aggressive behaviour

Aggressive behaviours were recorded through plastic IR dome colour CCTV cameras (2.8mm - 12mm, model 700TVL, Electrogear, Lansvale, NSW) mounted on the ceiling above each of the group-weaned treatment pens for days 1 and 2, and by placing Go-Pro cameras (model Hero3 white edition, GoPro Inc., San Mateo, CA, USA) on the feeder line on day 8 for both group-weaned treatment and stall treatment pens which were all in similar mixing pens.

Aggressive behavioural observations on days 1 and 2 were continuously observed only for the group-weaned treatment for 3h after introducing all sows to the pen on day 1 (observations commenced for Replicate 1 between 1015h and 1200h, Replicate 2 between 1000h and 1130h, and Replicate 3 between 0945h and 1145h, depending on the time of mixing of the pen) and 3h after releasing the sows from the stalls after feeding and boar exposure on day 2 (Replicate 1 at 1030h, Replicate 2 at 1030h, Replicate 3 at 1230h). The identity of the initiator and the receiver involved in each interaction were recorded. Aggressive behaviour was recorded as a whole, without attempting to differentiate between different types of aggressive behaviour (e.g. pressing, knock, bites), using an ethogram adapted from Hemsworth *et al.* (2013a; Table 1). If the interaction stopped for more than 5 s, any new behaviour displayed was considered to be part of a new interaction.

Table 1 - Ethogram of behaviours classified as aggressive behaviour. An interruption of more than 5 s was considered a new bout.

Behaviour	*Description*
Parallel pressing	Pigs stand side by side and push with shoulders against each other, throwing the head against the neck or head of the other
Inverse parallel pressing	Pigs face front to front and then push their shoulders against each other, throwing the head against the neck and flanks of the other.

Behaviour	Description
Head to body knocking	A rapid thrust upwards or sideways with the head or snout against any part of the body behind the ears. Most of the knocks are performed against the front half of the receiver. The performer's mouth is shut.
Head to head knocking	A rapid thrust upwards or sideways with the head or snout against the neck, head or ears of the receiver. The performer's mouth is shut.
Bite	A pig delivers a knock with the head against the head, neck or body of the other pig with the mouth open.

Aggressive behavioural observations on day 8 were observed for both the group-weaned treatment and the stall treatment, using the same ethogram as for days 1 and 2 (Table 1). However, this time, behaviours were continuously observed for the first 30 min after 1st feeding of being introduced to the pen in the morning (observations commenced for Replicate 1 at 0700h, Replicate 2 at 0700h, and Replicate 3 at 0730h), recording all interactions delivered and received for each sow within that period.

From the aggressive behaviour data on day 2, the aggression index for each sow was calculated as the ratio of aggression delivered to the total number of aggressive interactions (i.e. aggression delivered/(aggression delivered + aggression received)), varying from 0 to 1 (Hemsworth et al., 2013a). Sows were then classified as 'Dominant' if they delivered more aggression than they received (aggression index > 0.5), 'Subdominant' if they received more aggression than they delivered (aggression index >0.05, ≤ 0.5) and 'Submissive' if they delivered very little or no aggression (aggression index ≤ 0.05). This aggression index classification is similar to that devised by Mendl et al. (1992).

Sexual behaviour

Sexual behaviours were recorded through the plastic IR dome colour CCTV cameras (2.8mm - 12mm, model 700TVL, Electrogear, Lansvale, NSW) mounted on the ceiling above each of the group-weaned treatment pen. Sexual behavioural observations were conducted daily from days 3 to 6 using one-zero sampling during 5 min intervals every 30 min from 0730 to 1730h daily. The ethogram specifically developed for this study consisted of the behaviour displayed by the initiator of the sexual interaction: flank nosing, mounting, attempt to mount, unsuccessful mount, and ano-genital sniffing; and the behaviour displayed by the receiver: standing posture, flee to pen, flee to stall, aggressive and no reaction (see Table 2). The identity of the initiator and the receiver involved in each interaction were also recorded. If the interaction stopped for more than 5 s, any new behaviour displayed was considered to be part of a new interaction.

Table 2. Ethogram used for sexual behaviour recording. Each behaviour was scored as a 1 if it occurred within the sexual interaction bout observed or as a 0 if it did not occur. Hence, behaviours were not mutually exclusive. An interruption of more than 5 s was considered a new bout.

Behaviour - Initiator	*Description*
Flank nosing	Repeated contact with the flat tip of the nose to the flank area of another sow, where 'contact' is the snout touching or appearing to touch, i.e. within 5cm of the flank and 'repeated' is 2 or more sequential contacts or head movements.
Mount	2 legs on the back of another sow
Attempt to mount	The initiator is standing with the head or 1 leg on the back of another sow

Behaviour - Initiator	Description
Unsuccessful mount	Slipped on the floor, or attempt to mount bout < 2 s
Ano-genital sniffing	Flat tip of the snout of the sow is: orientated towards;_at the same height; and within 1 head distance of the vulva of another sow.
Behaviour - Receiver	
Standing posture	Immobile and stand upright for > 5 s, immobile stance, arched back and cocked ears
Flee to pen	Movement of two steps or more by the receiving sow away from the initiator to another location in the pen
Flee to stall	Movement of two steps or more by the receiving sow away from the initiator to a stall (including from one stall to a new stall)
Aggressive	Bite, knock, push
No reaction	No obvious behavioural reaction to the initiator
Other	Behaviour not listed above, e.g. sow in stall while being mounted.
Locked in stall	Sows have been moved into the stalls and locked in by staff for mating

2.4.6. Cortisol analysis

Blood samples were analysed for plasma cortisol concentration using an extracted RIA (Bocking et al., 1986), using hydrocortisone (H-4001; Sigma Chemical Co., St Louis, MO) as the standard. The assay utilized [3H]-cortisol (Amersham Pharmacia Biotech, UK, Buckinghamshire HP, England) as tracer and a dichloromethane extraction procedure.

2.5. *Statistical analyses*

All data was checked for normality and homogeneity of variance, and transformations applied as necessary (logarithmic or square root transformation). Data were analysed using a mixed model (Proc Mixed, SAS Inst. Inc., Cary, NC, USA). The experimental unit was the pig. The model included the effects of treatment (Group-weaned vs. stall), replicate (1 to 3) and the interactions of replicate and treatment, parity (1 and 3 to 6), pen nested within treatment, and age of the previous litter at weaning if significant. However, for the aggressive and sexual behaviours, pen was removed as a fixed effect and instead included as a random factor in the model. Furthermore, sexual behaviour initiated or received data were pooled by day and analysed as repeated measures across days 3 to 6. When significant differences ($P < 0.05$) were detected, Tukey-Kramer adjustments were used to account for the number of pairwise comparisons between treatments. If the data were not normally distributed and could not be transformed to fit normality (average duration of oestrus, stillborn piglets, mummified piglets), data were analysed using the Kruskal Wallis non-parametric test. For categorical data, Chi-square test was used, and Fisher's test if some of the cells had a frequency of 5 or less. Pearson correlations were conducted between variables of interest.

3. Outcomes

3.1. *Wean to mate (first insemination) interval and sexual receptivity test*

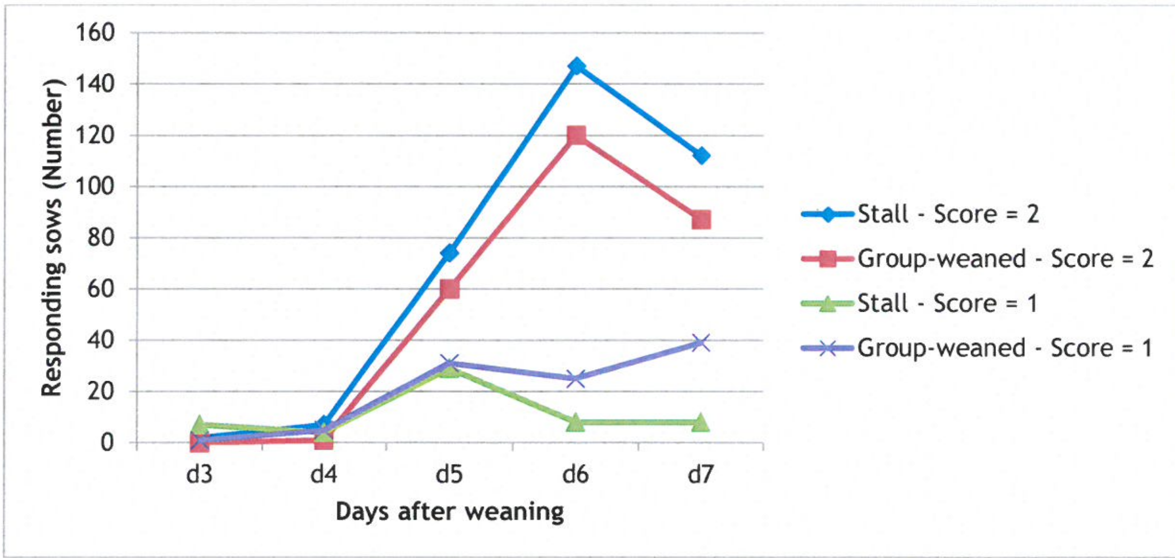
Overall, 90% of the sows showed oestrus-related behaviours by responding to the sexual receptivity test with a score of 1 or 2 between day 3 and day 7, with 21 sows failing to respond in the group-weaned treatment and 19 sows in the stall-housed treatment. Seven stall-housed sows started responding as soon as day 3 (scores of 1 or 2) to the sexual receptivity test whereas only 2 group-weaned sows responded on day 3 (Fisher's test P = 0.02; Table 3 and Figure 1), but treatments did not differ on Days 4 or 5 (Fisher's test P = 0.12 and Chi-square test P = 0.27, respectively). Stall sows still showed more responsiveness than group-weaned sows on Days 6 and 7 (Chi-square tests P = 0.002 and P = 0.0001 respectively). The overall length of oestrus, by counting the number of days that each sow responded to the sexual receptivity test with a score of 1 (response to the back-pressure test) or 2 (spontaneous standing response to boar exposure), did not differ overall between treatments (Group-weaned treatment: 2.09 ± 0.07 d vs. Stall treatment 2.23 ± 0.07 d, P = 0.18). Nevertheless, the length of the spontaneous standing to boar exposure was shorter in group-weaned sows as compared to stall-housed sows (Group-weaned treatment: 1.49 ± 0.08 d vs. Stall treatment 1.90 ± 0.07 d, Kruskal-Wallis test P < 0.0001). Group-weaned sows compensated by a longer length of response to the back-pressure test (Group-weaned treatment: 0.56 ± 0.06 d vs. Stall treatment 0.31 ± 0.04 d, Kruskal-Wallis test P = 0.0003).

Fewer sows were inseminated within 5 d after weaning (i.e. first insemination before or by day 6) in the group-weaned treatment as compared to the stall treatment (Group-weaned treatment: 147/180 sows or 81.7% vs. Stall treatment: 160/180 sows or 88.8%; Chi-square test P = 0.05). When considering all sows, the wean to mate (mating being based on the first insemination) interval was significantly longer by 1 d in the group-weaned treatment compared to the stall treatment (6.10 ± 0.31 d vs. 5.08 ± 0.31 d, P = 0.02), and parity had no effect (P = 0.17). However data contained numerous outliers (wean to mate interval from 6 to 28 days), with about two third of these outliers group-weaned sows and one third stall-housed sows and the coefficient of variation being greater for group-weaned groups than stall-housed groups (Group-weaned groups CV: 0.63 vs. Stall-housed groups CV: 0.37, P = 0.02). When considering only the sows mated within 5 d after weaning, the wean to mate interval was not different between the group-weaned treatment and the stall treatment (4.34 ± 0.05 d vs. 4.28 ± 0.05 d respectively, P = 0.30). Since only the sows that had received two inseminations by day 7 continued on the experiments, and a decision was made not to introduce unfamiliar sows into the group if less than 7 sows had been inseminated, 2 group-weaned groups retained only 6 sows out of 10 at day 7 and 3 groups retained only 5 sows, whereas only 1 stall group retained only 6 sows at day 7 (Table 8). The reason for not being retained at day 7 was mostly that these sows had not been mated twice by day 7, with only 3 sows being culled for lameness, vulva biting or poor condition (Table 8). This translated into 118 group-weaned treatment sows and 125 stall treatment sows remaining in these pens until farrowing. The wean to mate interval for sows inseminated within 5 d after weaning was negatively correlated with the length of oestrus (r = -0.62, P < 0.0001).

Table 3 - Sexual receptivity scores (i.e. 1 or 2) per treatment from Days 3 to 7.

Score frequency	Day 3	Day 4	Day 5	Day 6	Day 7	*Overall*
Stall = 1	7	4	29	8	8	*56*
Stall = 2	2	7	74	147	112	*342*
Group-weaned = 1	1	5	31	25	39	*101*
Group-weaned = 2	0	1	60	120	87	*268*
Overall Stall	**9**	**11**	**103**	**155**	**120**	***398***
Overall Group-weaned	**1**	**6**	**91**	**145**	**126**	***369***
P value	P = 0.02	P = 0.12	P = 0.27	P = 0.002	P < 0.0001	

Figure 1 - Sexual receptivity scores per treatment from Days 3 to 7 (day 3: P = 0.02, day 6: P = 0.002, day 7: P < 0.0001).



3.2. *Weight and gait score*

According to the random selection of sows, treatments did not differ in body weight on day 1 (N= 360, Group-weaned treatment: 245.6 ± 3.2 kg vs. Stall treatment: 246.8 ± 3.2 kg, P = 0.79). Treatments still did not differ in body weight on day 7 for the sows that remained on trial (N = 242, Group-weaned treatment: 240.6 ± 3.8 kg vs. Stall treatment: 244.9 ± 3.7 kg, P = 0.41). However, group-weaned treatment sows lost more weight over that first week after weaning in comparison to stall treatment sows, which is based on the sows that remained on trial after day 7 (N = 242, Group-weaned treatment weight gain: -2.78 ± 1.10 kg vs. Stall treatment weight gain: 0.27 ± 1.06 kg, P = 0.04), with the initial weight on day 1 and parity having significant effects as well (both P < 0.0001).

Very few poor gait scores were recorded, with 4 group-weaned treatment sows and 2 stall treatment sows scoring 1 (e.g. irregular gait) on day 1 and the rest scoring 0 (N = 360; **Fisher's test P = 0.68)**. This is probably due to the fact that sows with a score of 2 or 3 were excluded during treatment allocation, which corresponded to severely lame or non-weight bearing respectively. Treatments did not differ in gait score on day 7 with 9 group-weaned treatment sows scoring 1 and 1 group-weaned treatment sows scoring 2 while 4 stall treatment sows scored

1, which is based on the sows that remained on trial after day 7 (N = 242; Fisher's test P = 0.12).

3.3. *Aggressive behaviour, skin lesions and cortisol*

Aggression Day 1

The amount of aggression delivered or received by group-weaned sows over the first 3 h after weaning and mixing did not differ according to the replicate, parity or the age of the previous litter at weaning (all $P > 0.1$; Table 4), ranging from 4 to 15 bouts of aggression delivered or received between different pens over these 3 h after the initial mixing. The aggression index classification on day 1, i.e. whether a sow classified as a Dominant, Subdominant, or Submissive, did not differ between pens (Chi-square test P = 0.46), with overall 54 sows classified as dominant, 12 sows as subdominant and 114 sows as submissive. The amount of aggression received or delivered on day 1 did not correlate with the wean to mate interval, weight gain, length of oestrus, or parity (all $P > 0.1$).

Aggression Day 2

The amount of aggression delivered or received by group-weaned sows over the first 3 h after release from the stall after first feeding on the day following weaning and mixing did not differ according to the replicate, parity or the age of the previous litter at weaning (all $P > 0.1$; Table 4), ranging from 1 to 4 bouts of aggression delivered or received. The aggression index classification, i.e. whether a sow classified as a Dominant, Subdominant, or Submissive, did not differ between pens (Chi-square test P = 0.43), with overall 52 sows classified as dominant, 62 sows as subdominant and 66 sows as submissive.

The amount of aggression delivered correlated between days 1 and 2 (r = 0.29, $P < 0.0001$) but not the amount of aggression received (r = 0.05, P = 0.52). In terms of performance, the amount of aggression received or delivered on day 2 did not correlate with the wean to mate interval, weight gain, length of oestrus or parity (all $P > 0.1$). Furthermore, the aggression index classification on day 2 did not show any significant effect on the wean to mate interval, weight gain, or length of oestrus (all $P > 0.1$).

Table 4 - Aggressive behaviour for each pen on Days 1 and 2 (average number of bouts per sow; raw means ± SD).

Pen	1	2	3	4	5	6	7	8	9
Aggression Day 1									
Aggression delivered	7 ± 5	10 ± 7	4 ± 3	8 ± 6	11 ± 7	8 ± 3	8 ± 9	9 ± 6	13 ± 12
Aggression received	7 ± 5	10 ± 5	4 ± 3	8 ± 5	11 ± 7	8 ± 3	8 ± 4	9 ± 2	13 ± 9
Index classification (Dominant/Subdominant/Submissive)	2/0/8	2/0/8	0/1/9	3/1/6	2/0/8	3/0/7	5/1/4	5/1/4	2/0/8
Aggression Day 2									
Aggression delivered	2 ± 4	3 ± 4	1 ± 1	2 ± 2	2 ± 2	2 ± 2	2 ± 2	3 ± 3	4 ± 3
Aggression received	2 ± 3	3 ± 3	1 ± 1	2 ± 2	2 ± 2	2 ± 2	2 ± 1	3 ± 2	4 ± 4
Index classification (Dominant/Subdominant/Submissive)	2/6/2	3/4/3	1/8/1	3/4/3	3/1/6	2/5/3	2/2/6	2/3/5	4/2/4

Pen	10	11	12	13	14	15	16	17	18
Aggression Day 1									
Aggression delivered	9 ± 17	14 ± 21	7 ± 7	11 ± 16	15 ± 12	9 ± 8	8 ± 9	6 ± 5	7 ± 7
Aggression received	9 ± 4	14 ± 5	7 ± 5	11 ± 4	15 ± 7	9 ± 5	8 ± 4	6 ± 2	7 ± 5
Index classification (Dominant/Subdominant/Submissive)	2/3/5	3/2/5	4/0/6	2/1/7	4/0/6	3/0/7	3/1/6	5/0/5	4/1/5
Aggression Day 2									
Aggression delivered	1 ± 1	1 ± 2	3 ± 4	4 ± 4	1 ± 2	3 ± 6	3 ± 3	3 ± 2	4 ± 4
Aggression received	1 ± 1	1 ± 1	3 ± 3	4 ± 5	1 ± 1	3 ± 3	3 ± 3	3 ± 2	4 ± 3
Index classification (Dominant/Subdominant/Submissive)	3/4/3	3/6/1	4/1/5	3/3/4	2/4/4	3/2/5	3/3/4	6/1/3	3/3/4

Aggression Day 8
Group-weaned and stall-housed treatments between weaning and insemination did not influence the amount of aggression delivered or received on day 8 (P = 0.49 and P = 0.37, respectively; Table 5), but the replicate had an effect (P = 0.01 and P = 0.03, respectively). More aggression was delivered in replicate 3 (means ± SD: 3.8 ± 3.7) as compared to replicates 1 and 2 (means ± SD: 2.1 ± 2.7 and 3.0 ± 4.8, respectively; Tukey post-hoc tests P = 0.02 and P = 0.04). More aggression was also received in replicate 3 over replicate 1 (means ± SD: 4.0 ± 3.6 vs. 2.1 ± 2.7, Tukey post-hoc tests P = 0.03), replicate 2 being intermediate (means ± SD: 3.0 ± 4.0, both Tukey post-hoc tests P > 0.10). The interaction of treatment and replicate was not significant (Aggression delivered: P = 0.97, aggression received: P = 0.95). The aggression index classification at day 8 did not differ between group-weaned and stall-housed sows (Chi-square test P = 0.83).

Table 5 - Aggressive behaviour for each treatment on Day 8 (LS-means ± SEM).

	Group-weaned	Stall	SEM	P value
Aggression Day 8 (number)				
Aggression delivered*	0.4 (2.4)	0.5 (3.5)	0.04 (0.4)	P = 0.49
Aggression received*	0.4 (2.6)	0.5 (3.5)	0.05 (0.4)	P = 0.37
Index classification (Dominant/Subdominant/Submissive)	42/29/47	39/33/46		P = 0.83

* These data were analysed using the log transformation log(x+1) and is presented as transformed LS-means value with its non-transformed LS-means value in parenthesis.

Cortisol concentration

Group-weaned sows had higher cortisol concentrations than stall-housed sows on day 2, the day following weaning (N= 105, P = 0.001; Table 6). The aggression index classification based on aggression on day 2 had no effect on cortisol concentration on day 2 (P = 0.30). Cortisol concentration on day 2 negatively correlated with weight gain over the first week after weaning (r = -0.18, P = 0.004), and positively correlated with parity (r = 0.32, P < 0.0001). Cortisol concentration on day 2 did not correlate with the wean to mate interval or length of oestrus (all P > 0.1). There was also no significant correlation between the amount of aggression received or delivered on day 2 and cortisol concentration (r = 0.20, P = 0.15 and r = 0, P = 0.93, respectively).

Treatments did not differ in cortisol concentrations on day 8, the day following grouping for the stall sows or regrouping for the group-weaned sows (N = 104, P = 0.22). The aggression index classification based on aggression on day 8 had a significant effect on cortisol concentration on day 8 (P = 0.004), with subdominant sows (16.1 ± 1.3 ng/mL) having higher cortisol concentration than submissive sows (10.0 ± 1.1 ng/mL, Tukey post-hoc test P = 0.003) and dominant sows (11.9 ± 1.2 nmol/L) tending to be higher than submissive sows (Tukey post-hoc test P = 0.06). Out of the 108 sows blood sampled, 78 (72%) continued on the second week allowing an individual comparison between days 2 and 8, hence controlling for individual variability. However, day 2 concentrations had no influence on day 8 cortisol concentrations (N = 78; P = 0.08).

Skin lesions

Group-weaned sows had higher total and fresh skin lesions than stall-housed sows on day 2 (both $P < 0.0001$), the day following weaning, but both the replicate as main effect and the interaction between treatment and replicate were significant (both $P < 0.0001$), with about 3 to 4 times more fresh lesions for group-weaned sows in replicates 2 and 3 (Tukey post-hoc tests both $P < 0.0001$; Table 6), but no difference between treatments in replicate 1 (Tukey post-hoc tests: Total skin lesions $P = 0.21$; Fresh skin lesions $P = 0.16$). The aggression index classification at day 2 or parity had no effect (both $P > 0.1$). Total and fresh skin lesion scores at day 2 were positively correlated with cortisol concentration at day 2 (both $r = 0.20$, $P < 0.0005$) and negatively correlated with weight gain (both $r = -0.13$, $P = 0.0004$). Total and fresh lesions score at day 2 were also positively correlated with parity ($r = 0.11$, $P = 0.0005$ and $r = 0.09$, $p = 0.004$, respectively). However, total and fresh lesion lesion scores did not correlate significantly with the wean to mate interval or the length of oestrus (all $P > 0.1$).

On day 8, the day following grouping for the sows previously housed in stalls or moving for the group-weaned sows, sows previously housed in stall and recently mixed had 4 times the amount of fresh skin lesions compared to group-weaned sows ($P < 0.0001$; Table 6), and the replicate effect was significant ($P < 0.0001$) but not the interaction of treatment and replicate ($P = 0.18$). Treatments did not differ in their main effect for total (i.e. fresh and old) skin lesions on day 8 ($P = 0.53$), but the replicate as main effect and the interaction between treatment and replicate was significant (both $P < 0.0001$). In replicates 1 and 2, stall sows had more total lesions than group-weaned sows (Tukey post-hoc tests $P < 0.0001$ and $P = 0.02$, respectively), but in replicate 3, group-weaned sows had more total lesions than stall sows (Tukey post-hoc test $P < 0.0001$).

Table 6 - Cortisol concentrations and skin lesion scores per treatment for days 2 and 8 (LS-means ± SEM).

	Group-weaned	Stall	P value
Cortisol (ng/mL)			
Day 2	26.0 ± 1.6	18.7 ± 1.6	P = 0.001
Day 8	11.5 ± 1.5	14.1 ± 1.5	P = 0.22
Skin lesions (number)			
Day 2 Total skin lesions			
Replicate 1	9.7 ± 1.5	6.5 ± 0.9	P = 0.21
Replicate 2	15.9 ± 1.5	5.6 ± 1.5	P < 0.0001
Replicate 3	25.7 ± 1.5	6.9 ± 1.5	P < 0.0001
Day 2 Fresh skin lesions			
Replicate 1	8.8 ± 1.5	5.9 ± 1.5	P = 0.16
Replicate 2	15.6 ± 1.5	5.4 ± 1.5	P < 0.0001
Replicate 3	25.2 ± 1.5	6.6 ± 1.5	P < 0.0001
Day 8 Total skin lesions			
Replicate 1	15.7 ± 3.0	36.6 ± 3.0	P < 0.0001
Replicate 2	13.5 ± 3.2	23.8 ± 3.0	P = 0.02
Replicate 3	46.7 ± 3.0	20.2 ± 3.0	P < 0.0001
Day 8 Fresh skin lesions			
Replicates 1 to 3	7.2 ± 1.5	24.0 ± 1.5	P < 0.0001

3.4. *Sexual behaviour of sows grouped at weaning*

The number of sexual behaviour bouts initiated and received by group-weaned sows varied daily, between days 3 and 6 after weaning ($P < 0.0001$ and $P < 0.0001$, respectively; Table 7). Sexual behaviour initiated peaked on day 5 but was still elevated on day 6. Sexual behaviour received also peaked on day 5 as compared to all other days, and sows were still receiving higher number of sexual behaviour on day 6 as compared to days 3 and 4. Sexual behaviour received also differed according to the replicate ($P < 0.0001$) and the interaction of day and replicate ($P = 0.005$) with an effect of day for replicates 1 and 3 but not replicate 2 (Tukey post-hoc tests $P < 0.0001$, $P < 0.0001$ and $P = 0.24$, respectively).

The overall frequency of sexual behaviour bouts initiated or received between days 3 and 6 did not differ according to the aggression index classification on day 2 (both $P > 0.1$). However, the frequency of sexual behaviour bouts initiated differed according to the aggression index classification on day 8 (both $P = 0.04$) with dominant sows initiating more sexual behaviour (27.9 ± 3.1) compare to subdominant (22.3 ± 3.6, Tukey post-hoc test $P = 0.03$) and submissive sows being no different (16.7 ± 3.2, Tukey post-hoc tests $P = 0.46$ and $P = 0.47$). The frequency of sexual behaviour received did not differ based on the aggression index classification on day 8 ($P = 0.35$).

The overall frequency of sexual behaviour bouts initiated between days 3 and 6 differed according to parity ($P = 0.04$ and $P = 0.0003$, respectively), with parity 1 sows initiating less sexual behaviour than parity 6 sows (14.9 ± 3.1 vs. 31.7 ± 4.6, Tukey post-hoc test $P = 0.03$). Parity 1 sows also showed less sexual behaviour received (12.0 ± 3.4) than parities 4 and 5 sows (Parity 4: 28.7 ± 3.9, Tukey post-hoc test $P = 0.02$; Parity 5: 36.7 ± 4.1, Tukey post-hoc test $P < 0.0001$).

In terms of specific sexual behaviour initiated, ano-genital sniffing was the most common behaviour displayed by the initiator from day 3 to day 5, observed in more than half of the sexual behaviour bouts, but it declined on day 6, whereas flank nosing increased on day 6 (Table 9). Mounting increased on day 5 and unsuccessful mounts on day 6, whereas attempts to mount were at their maximum on days 5 and 6. When all forms of mounting behaviour were considered (successul mounts, attempts to mount and unsuccessful mounts), all forms of mounts increased from day 3 to day 6, but it was only seen in less than 5% of the sexual behaviour interactions.

In terms of specific sexual behaviour received, i.e. the reaction from the recipient sow, sows showed no reaction in about half of the sexual behaviour interactions but rarely adopted a standing posture (Table 9). Sows avoided started sexual behaviour interactions more on day 6 than on day 3, as indicated by the fleeing, and aggression was observed more on day 6 than on day 4.

Ano-genital sniffing differed according to the aggression index classification based on aggression on day 8 ($P = 0.02$), with more ano-genital sniffing displayed by dominant sows (21.7 ± 2.2) compare to subdominant sows (12.7 ± 2.2, Tukey post-hoc test $P = 0.01$), submissive being no different (16.4 ± 2.5). The aggression index classification at day 2 or 8 had no effect on the other specific sexual behaviour (all mounting behaviours combined, flank nosing, standing posture, fleeing to pen or stall, aggression or no reaction).

A few specific sexual behaviour differed according to parity, with more mounts (successful mounts, attempts to mount and unsuccessful mounts combined, $P = 0.03$) for parity 6 sows over parity 3 (2.9 ± 0.6 vs. 0.6 ± 0.6, Tukey post-hoc test $P = 0.04$). Ano-genital sniffing also differed according to parity ($P <$

0.0001), with more sniffing in parities 4 and 6 sows as compared to parity 1 sows (19.0 ± 2.6 and 24.8 ± 2.7 vs. 8.2 ± 1.9, Tukey post-hoc tests P = 0.008 and P < 0.0001, respectively) and less in parity 5 sows than in parity 6 sows (parity 5: 12.1 ± 2.8, Tukey post-hoc test P = 0.01). No reaction to a sexual behaviour interaction also differed according to parity (P = 0.004), with parity 1 sows less often displaying no reaction (6.6 ± 1.7) compared to parities 4, 5 and 6 sows (14.3 ± 2.0, 15.8 ± 2.0 and 16.1 ± 2.1, Tukey post-hoc tests P = 0.03, P = 0.006 and P = 0.006, respectively).

Relating sexual behaviour to reproductive performance, the overall frequency of sexual behaviour bouts initiated between days 3 and 6 was positively correlated with the length of oestrus, as measured by the sexual receptivity test (r = 0.17, P = 0.02), and there was a trend for the frequency of sexual behaviour initiated to correlate negatively with weight gain (r = -0.17, P = 0.07). The overall frequency of sexual behaviour bouts received between days 3 and 6 was positively correlated with cortisol concentration on day 2 (r = 0.33, P = 0.02), and also positively correlated with the length of oestrus (r = 0.15, P = 0.04).

Relating specific sexual behaviours to reproductive performance, the frequency of ano-genital sniffing performed by the initiator was positively correlated with the length of oestrus (r = 0.18, P = 0.02), but tended to be negatively correlated with weight gain (r = -0.17, P = 0.07). The number of times a sow did not react to a sexual behaviour interaction was positively correlated with the length of oestrus (r = 0.16, P = 0.03), but also positively correlated with cortisol concentration at day 2 (r = 0.30, P = 0.03). Similarly, fleeing the interaction by moving to another area of the pen was positively correlated with the length of oestrus (r = 0.21, P = 0.004), and positively correlated with cortisol concentration at day 2 (r = 0.41, P = 0.003).

Table 7 - Sexual behaviour initiated and received by day (average number of bouts per sow; LS-means ± SEM). Letters with different subscripts differ (P < 0.01)

	Day 3	Day 4	Day 5	Day 6	SEM	P-value
Sexual behaviour initiated*	0.9^{a} (2.9)	1.1^{ab} (3.9)	1.4^{c} (7.5)	1.2^{bc} (5.4)	0.1 (0.6)	P < 0.0001
Sexual behaviour received	3.5^{a}	4.6^{ab}	8.0^{c}	5.5^{b}	0.4	P < 0.0001

*These data were analysed using the log transformation log(x+1) and is presented as transformed LS-means value with its non-transformed LS-means value in parenthesis.

Table 8 - Sexual behaviour initiated and received for each pen between days 3 and 6 (average number of bouts per sow; raw means ± SD) and insemination rate (number of sows per pen having received two inseminations by day 7) and culls.

Pen	1	2	3	4	5	6	7	8	9
Sexual behaviour initiated	2± 4	6 ± 10	3 ± 4	9 ± 13	3 ± 6	6 ± 7	3 ± 4	2 ± 3	6 ± 8
Sexual behaviour received	0 ±0	9 ± 6	5 ± 5	10 ± 9	3 ± 2	8 ± 7	3 ± 2	2 ± 2	4 ± 4
Insemination rate	9	9	6	9	7	10	7	5	9
Cull	0	0	0	0	0	0	1	0	0

Pen	10	11	12	13	14	15	16	17	18
Sexual behaviour initiated	2 ± 4	2 ± 3	4 ± 9	4 ± 7	8 ± 14	6 ± 8	5 ± 6	7 ± 6	10 ± 14
Sexual behaviour received	2 ± 2	2 ± 1	3 ± 4	4 ± 4	9 ± 9	7 ± 6	6 ± 4	8 ± 5	12 ± 7
Insemination rate	8	9	6	9	6	10	9	9	8
Cull	0	0	1	0	1	0	0	0	0

Table 9 - Specific types of sexual behaviour initiated and received by day (as percentage of the overall sexual behaviour initiated and received bouts observed; LS-means ± SEM). Letters with different subscripts differ ($P < 0.05$). Behaviours were not mutually exclusive, hence they could occur in the same bout of sexual behaviour.

	Day 3	Day 4	Day 5	Day 6	SEM	P-value
Sexual behaviour initiated (%)						
Flank nosing	6.4^{a}	7.5^{a}	7.8^{a}	14.2^{b}	1.7	P < 0.0001
Ano-genital sniffing	58.8^{a}	59.1^{a}	60.6^{a}	47.9^{b}	4.0	P = 0.005
Mounts	0.0^{a}	0.2^{a}	1.2^{b}	0.8	0.4	P = 0.007
Attempts to mount	0.5^{a}	2.0	2.2^{b}	2.6^{b}	0.7	P = 0.01
Unsuccessful mounts	0.1^{a}	0.1^{a}	0.6	1.3^{b}	0.3	P = 0.0003
*All forms of mounts**	0.6^{a}	2.3^{ab}	4.0^{bc}	4.7^{c}	0.9	P < 0.0001
Sexual behaviour received (%)						
No reaction	50.7^{a}	46.6	42.3^{b}	44.5	2.7	P = 0.01
Standing posture	0.0	0.4	0.6	0.0	0.3	P = 0.06
Flee to pen	3.9^{a}	5.4	7.5	8.7^{b}	1.4	P = 0.005
Flee to stall	0.4	0.9	1.3	1.4	0.6	P = 0.32
Aggression	0.8	0.5^{a}	1.6	2.4^{b}	0.7	P = 0.03
Other	26.4	28.3	28.8	25.1	2.5	P = 0.42

*Mounts, attempts to mount and unsuccessful mounts combined.

3.5. *Conception, farrowing and litter characteristics*

Conception rate based on the percentage of sows confirmed pregnant through ultrasound and returns 5 weeks after insemination did not differ between treatments (Chi-square test P = 0.62; Table 10). The insemination to farrow interval also did not differ between treatments (P = 0.87; Table 10), but the age of the previous litter at weaning, hence at the start of the treatments, had a strong effect on the mate to farrow interval (P < 0.0001). Nevertheless, age of the previous litter at weaning and mate to farrow interval were not correlated (r = 0.0, P = 0.94). The wean to mate interval had no effect on mate to farrow interval (P = 0.18) and wean to mate and mate to farrow intervals were not correlated (r = -0.07, P = 0.25). Farrowing rate did not differ between treatment (Group-weaned treatment: 150/180 sows or 83.33% vs. Stall treatment: 152/180 sows or 84.44%; Chi-square test P = 0.77; Table 10).

The total number of piglets born did not differ between treatment (P = 0.83). The number of piglets born alive did not differ between treatments (P = 0.30), but was influenced by the age of the previous litter at weaning (P = 0.02). However, the number of piglets born alive and the age of the previous litter at weaning were not correlated (r = 0, P = 0.99). The number of piglets stillborn did not differ between treatments (Kruskal-Wallis test P = 0.12), nor did the number of piglets born mummified (Kruskal-Wallis test P = 0.24).

All the data regarding pregnancy, farrowing and litter characteristics showed similar results whether all sows that started the trial were considered, as done here (N = 360; Table 10), or whether only the sows that remained under experimental conditions after day 7 after weaning were included in the statistical analyses (N = 243; Table 11).

Table 10 - Mate to farrow interval, farrowing rate, and litter characteristics between treatments for all sows that started the trial (N = 360; LS-means ± SEM).

	Group-weaned	Stall	P value
Pregnancy check (Positive / Returns / Culls and missing values; numbers)	168 / 6/ 6	161/ 10 /9	P = 0.62
Mate to farrow interval (d)	116.8 ± 0.1	116.8 ± 0.1	P = 0.87
Farrowing rate (%)	83.33	84.44	P = 0.77
Total piglets born (numbers)	12.6 ± 0.2	12.6 ± 0.2	P = 0.83
Piglets born alive (numbers)	11.4 ± 0.2	11.8 ± 0.2	P = 0.30
Piglets stillborn (numbers)	0.9 ± 0.1	0.7 ± 0.1	P = 0.12
Piglets mummified (numbers)	0.26 ± 0.08	0.19 ± 0.08	P = 0.24

Table 11 - Pregnancy check outcomes, mate to farrow interval, farrowing rate, and litter characteristics between treatments for the sows that remained on trial after day 7 (N = 243; LS-means ± SEM).

	Group-weaned	Stall	P value
Pregnancy check (Positive / Returns / Culls and missing values; numbers)	114 / 3 / 1	116 / 4 / 5	P = 0.73
Mate to farrow interval (d)	116.9 ± 0.2	117.0 ± 0.2	P = 0.96
Farrowing rate (%)	95.76	90.40	P = 0.10
Total piglets born (numbers)	12.6 ± 0.3	12.8 ± 0.3	P = 0.63
Piglets born alive (numbers)	11.5 ± 0.3	11.9 ± 0.3	P = 0.28
Piglets stillborn (numbers)	0.9 ± 0.1	0.7 ± 0.1	P = 0.66
Piglets mummified (numbers)	0.26 ± 0.09	0.13 ± 0.09	P = 0.09

3.6. *Discussion*

Ninety-percent of the sows displayed oestrus-related behaviours within the first week after weaning, based on the sexual receptivity test, with no overall difference between group-weaned sows and individually stall-housed sows and no obvious delay in the onset of oestrus based on daily tests. Testing every 8 h, Langendijk et al. (2000) reported that group-weaning postponed the onset of oestrus by 10 h in comparison to individual stall housing, while others found no effect (England and Spurr, 1969; Sommer, 1979) or even positive effects (Hemsworth et al., 1982; Pearce and Pearce, 1992), although the average onset of oestrus in these last two studies was more than 10 d after weaning. The length of oestrus-related behaviours was also not affected by group-weaning, based on sows that came in oestrus between day 3 and day 7 after weaning, in accordance with Langendijk et al. (2000). Nevertheless, group-weaned sows displayed fewer spontaneous standing responses to boar exposure which were partly compensated by higher responses to the back-pressure test in presence of the boar. This means that more group-weaned sows were detected by manual testing by a stockperson performing the back pressure test in the presence of the boar than stall-housed sows. England and Spurr (1969) reported no difference in detection rate between group-housed or stall-housed sows. Yet, different methods of oestrus detection can influence the likelihood of successfully detecting sows in oestrus (Kemp et al., 2005). In fact, Langendijk et al. (2000) found that group-weaning delayed oestrus detection by the back-pressure test in presence of the boar, but not when using the spontaneous standing response to the boar, for which our study found the strongest effect. This discrepancy between ours and Langendijk et al. (2000)'s findings may be due to their lower sample size for their spontaneous-oestrus test (n=28 stall-housed and n=23 group-housed sows in Langendijk et al. (2000); vs. n=180 sows for each treatment in our study). Indeed, our findings concur with the idea that the incidence of 'silent oestrus' may be much higher with less intensive oestrus detection protocols (Kemp et al., 2005), in our case spontaneous standing to the boar being less intensive than the back-pressure test. These results indicate that group-housed sows may be less receptive than stall-housed sows, based on their differential responses to the boar and the back-pressure test in presence of the boar, and highlight that efficient oestrus detection methods may be relatively more important for group-weaning systems that stall-weaning systems.

The wean to mate interval did not differ significantly, when considering sows that came into oestrus within 5 days of weaning, which is consistent with the previous literature (England and Spurr, 1969; Fahmy and Dufour, 1976; Karlberg 1980). Yet, there was 7% less group-weaned sows than stall-housed sows inseminated twice within 6 days of weaning. The protocol for this study, whereby sows had to be moved within 6 days of weaning, meant that sows that had not received two inseminations by this time were discarded. This outcome suggests that there may be greater variation in group-weaned sows, as shown in the present study in two of the 18 pens retained 6 sows out of 10, and three of these pens 5 sows out of 10, whereas only one group of stall-housed sows retained 6 sows. Hence, the numbers of sows that dropped out of the system were more uneven for group-weaned sows when attempting to keep static groups of seven familiar sows after day 7 out of an initial group of ten sows. Only 3 sows were culled due to lameness, vulva biting or poor condition whereas most sows were removed because they have not been mated twice by day 7. This is consistent with Langendijk et al. (2000) who also found greater variation between the first and last sow showing oestrus in group-weaned sows compare to stall-housed sows, and Hansen (2003b) who suggested that group-weaned sows have later oestrus. The greater variation in oestrus behaviours found in this study and by others (Pedersen et al., 1993; Langendijk et al., 2000) suggests that sows may differ in their susceptibility to stress (Turner et al., 2002). It is well recognized that reproductive performance is affected by stress (Kongsted, 2004; Pedersen et al., 2007) but direct evidence remained scarce to date (Turner et al., 2005).

A combination of stress indicators were collected in this study, aggressive behaviours delivered and received, skin lesion scores and cortisol. As expected, group-weaned sows had a higher amount of fresh skin lesions than stall sows on the day following weaning (day 2) and the reverse occurred on the day following moving (day 8) when the recently mixed stall sows had more fresh skin lesions than group-weaned sows which were moved but kept in familiar groups. The effect on cortisol concentrations was similar for day 2, with group-weaned sows showing higher cortisol concentrations than sows weaned in stalls. However, the recently mixed stall sows did not differ from group-weaned sows on the day following moving (day 8) and both treatments showed a reduction in cortisol concentrations from days 2 to 8 and no difference in aggression for the first 30 min after feeding on day 8. Both cortisol and aggressive behaviours recorded over the first 30 min after the 1st feeding are reliable indicators of aggression-induced stress (Hemsworth et al., 2013b). This suggests that sows may be more responsive to stressors, such as mixing, after weaning compared to after insemination. Although there is evidence that other species may vary in their response to stressors according to the stage of reproduction, there is no evidence of this in the sow. It is important to note that most studies have looked at mixing after 4 weeks of pregnancy in order not to disturb embryo implantation (for reviews see Arey and Edwards, 1998; Spoolder et al., 2009) whereas in the present study, grouped and stall-housed sows were mixed within 48 h of the first insemination. This attenuation in cortisol response and aggressive behaviour on day 8 compared to day 2 may also result from the fact that group-weaned sows had to cope with a greater combination of stressors on day 2, namely a new social environment in addition to weaning. Interestingly, the aggression index classification (Dominant, subdominant or submissive) based on day 8 correlated with cortisol concentration on the same day and with some sexual behaviours, but this was not true for the aggression index based on the aggression on day 2. The aggression on day 8 and the derived index were calculated based on observations 30 min after first feeding (validated by Hemsworth et al., 2013a) whereas the aggression on day 2 was observed for 3 h after feeding and release from the stalls, due to pen design, which may have influenced the aggression recorded. In terms of consequences of this social stress, both cortisol concentration and skin lesion scores on day 2 negatively correlated with weight gain over the first week after weaning, suggesting that stressed sows performed poorly over that first week. However, we found no evidence that this stress affected sexual responsiveness or wean to mate interval, whereas Pedersen et al. (1993) reported that aggression received correlated positively with wean to oestrus interval and negatively with the duration of oestrus.

Sexual behaviours were the subject of detailed observations daily in the group-weaned treatment from days 3 to 6 after weaning. Sexual behaviour peaked on day 5 and remained high on day 6, the last day of observation. Most of the sexual behaviours observed consisted of ano-genital sniffing, but flank nosing and mounting behaviours increased on days 5 and 6. However, mounting behaviour was only seen in less than 5% of the sexual behaviour interactions, and flank nosing in about 8 to 14%, four and five days after weaning. Different methods of observation may lead to differences in observed prevalence of these behaviours, although our method was designed to capture most of the daily pattern, since sexual behaviour occurs throughout the day and the night (Pedersen, 2007). Nevertheless, flank nosing and mounting remain potential injurious behaviours to the sows. Sows that were the target of these sexual behaviours showed no reaction in about half of the interactions. They rarely adopted a standing posture, which suggests that the sow initiating the interaction, not the sow targeted, was the sow in oestrus. Sows started fleeing from sexual behaviour interactions when these interactions were at their peak, and in rare instances targeted sows would respond in an aggressive manner. The frequency of sexual behaviour displayed correlated with the number of days sows were detected in oestrus. The frequency of sexual behaviour initiated tended to correlate with lower weight gain over the first week after weaning, suggesting that this sexual activity may result in higher energy expenditure or stress. In fact, the frequency of sexual behaviour received was correlated with cortisol concentration on day 2. Cortisol concentration at day 2 obviously was not affected by those sexual behaviours received later in the week, but both measures may related to a common variable, such as the type of sows targeted by both mixing stress and sexual behaviour interaction. Dominant sows, based on the classification on day 8 (but not day 2), performed more of those sexual behaviours than subdominant or subordinate sows, which is in agreement with Pedersen (2007). However, there was no evidence that recipient sows are chosen based on their dominance status.

Group-weaned sows showed greater weight loss over the first week after weaning. This outcome is likely linked to the higher stress levels that group-weaned sows experienced during this first week after weaning, either due to aggression, sexual behaviour, or a combination of both factors. This is unlikely related to competition for food as group-weaned sows had access to individual feeding stalls which were used to lock sow for the first feed on the day and these sows were provided with 2.7kg per sow three times daily for the first week after weaning, in other words fed *ad libitum*. Group-weaned sows did not differ in gait score from stall-housed sows. This is in agreement with the literature with reports that mounting behaviour had no effect on the incidence of lameness in group-weaned sows (Hansen et al., 2013). However, sows that were removed from the trial at moving one week after weaning in the present study, particularly those that did not show oestrus-related behaviour (21 sows or 11.7% in the group-weaned treatment) could have been most affected. Unfortunately, weight and gait scores were not collected on these sows at day 7, leaving this question unanswered.

Grouping sows after weaning or after insemination did not have any significant long-term effects beyond the first week after weaning on conception rate and returns 5 weeks after mating, mate to farrow interval, or litter characteristics at farrowing. However, the sample size was relatively small to test effects on farrowing performances, which are usually detected using much larger sample sizes. For instance, group housing after weaning was found to increase litter size (Hemsworth et al., 1982; by +0.27 piglets), decrease litter size (Hansen, 2000; by -0.30 piglets, n≈938 litters per treatment), or no effect on litter size (Hansen, 2003a; n≈670 litters per treatment) compared to stall housing after weaning. It has also been found to increase farrowing rate by 4% without affecting litter size (Hansen, 2003b; n≈1,300 litters per treatment).

Boar stimulation is an important stimuli that can modulate the onset of oestrus, hence the weaning to mating interval, both in terms of frequency, intensity and length of boar stimulation (Hemsworth et al., 1982; Langendijk et al., 2000; Kemp et al., 2005). Boar stimuli can stimulate oestrus (Kemp et al., 2005), but continuous boar contact should be avoided since it can suppress the expression of oestrus behaviour (Hemsworth and Hansen, 1990; Tilbrook and Hemsworth, 1990; Knox et al., 2004). Boar stimulation in the present study was provided once daily between days 2 and 7, but boar exposure was controlled by locking group-weaned sows in their feeding stalls for about 2 h daily and allowing 30 s of boar exposure to each sow. A majority of studies used the back-pressure test as a measure of receptivity, but only a few studies include parameters of proceptivity, although proceptivity may serve to stimulate fertilisation (de Jonge et al, 1994; Pedersen, 2007). Proceptivity could ease management by removing the need to lock group-weaned sow for boar exposure if they approach on their own will while in oestrus. The effects of leaving group-weaned sow freely interacting with the boar (i.e. proceptivity) and different frequencies or lengths of boar exposure, require further research.

4. Application of Research

The interpretations from these findings are:

- Housing sows in groups from weaning to insemination led to increased variability in receptivity and mating success, with 7% less sows retained within 6 days after weaning after having been mated twice. Five out of 18 group-weaned groups retained less than 7 sows out of 10 (with three of these retaining only 5 sows), whereas one stall group only retained 6 sows. Thus housing sows in groups after weaning, depending on when sows are transferred to gestation accommodation, may lead to greater variability in numbers of sows in weekly gestation batches and in turn greater variability in the output of weekly batches of farrowing sows.
- Sows weaned in groups show less intense displays of receptivity, suggesting that more effective oestrus detection protocols are necessary for group-weaning systems.
- Sows mixed after weaning had higher levels of stress than stall-housed sows post-weaning, based on cortisol concentrations, aggression and skin injuries on day 2. However, on day 8 post-weaning, recently-mixed stall-housed had greater skin injuries than sows group-weaned but moved to another group pen at day 7 but the two treatments of sows had similar levels of aggression and stress at day 8. Group-weaned sows also lost 2.8 kg of body weight during the first week post-weaning, at a time where they should be gaining after weight lost during lactation.
- Research on a larger sample size is needed to have sufficient statistical power to compare the effects of housing sows from weaning in groups or stalls on reproductive variables, and therefore potential practical and economic implications.

5. Conclusion

The scientific literature on group-housing sows after weaning shows considerable inconsistency and conflicting results, partly due to the use of different housing, management systems, genetics and environmental effects. This project showed that, using what may be considered close to industry best practices, group-weaned sows experienced higher levels of stress and aggression during the first week after weaning compared to sows kept in stalls for that first week and mixed after mating. Both aggression and sexual behaviour between sows are likely to contribute to this stress. The most evident productivity outcome was that group-weaned sows experiencing lost 2.8 kg of body weight during the first week after weaning, at a time where they should be gaining after weight lost during lactation, while stall-housed sows remained stable. Nonetheless, the fact that 7% less group-weaned sows were inseminated within 5 days of weaning combined with a higher variability in retention rate (being mated twice and not culled) within 6 days of weaning between pens of weaned sows is probably the greatest concern for industry by reducing the predictability of the system. Oestrus-related behaviour were less obvious in group-weaned sows, but they still performed equally well in terms of wean to mate interval. Investigating the impact of grouping sows after weaning on farrowing performances requires a larger sample size than this innovation project allowed.

6. Limitations/Risks

- These research findings are likely an underestimation of the real risks for industry-type settings, since this experiment used what may be considered, industry best practices, to minimise aggression and optimise oestrus detection:
- Group-weaned sows were mixed at 4.4 m^2 per sow. Previous work (Hemsworth et al., 1986) suggest that space allowance can affect oestrous expression, with better results at 3 m^2 compared to 1 or 2m^2 per sow. Hence, the use of smaller space allowances could even lower further oestrous expression.
- Group-weaned sows were segregated by parities, fed *ad libitum*, and locked in full-body feeding stalls during the first feed of day (for boar exposure and mating purposes). Hence competition for feed was limited in comparison to systems like restricted feeding, floor-feeding, or multiparous groups of sows.
- Group-weaned sows were kept in static groups (i.e groups of familiar sows) following mating, whereas industry may need to manage, at least partly, dynamic groups (i.e. introduce unfamiliar sows) to keep uniform group size and full pen density after mating, given the variability in insemination rate.
- Group-weaned sows were locked in feeding stalls to ensure controlled boar exposure for 30 s daily, back-pressure tested daily from day 3 to day 7 after weaning to ensure all sows in oestrus were detected, and an attempt was made to keep sows locked for 2h+ after insemination to avoid stress immediately post-insemination.
- The experiment was conducted in the winter of southern New South Wales (September), and seasonal effects may operate.
- The mixing pens used after weaning and after mating differed in characteristics (space allowance per sow, feeding systems, group size) and therefore straight comparison of the aggression levels seen after weaning compared to after mating are not possible, although the characteristics (space, full body-stall) of the mixing pen at weaning should have limited aggression. Principles to reduce aggression at mixing should be sought, and techniques used to reduce aggression when mixing after mating may be directly applicable or require adaptation.

7. Recommendations

As a result of the outcomes in this study the following recommendations are made:

- Elucidate the effects of pen characteristics for mixing after weaning (ability to escape aggression, hide areas, feeding system, space allowance, floor type, environmental enrichment) to minimize competition for resources and to allow avoidance of sexual interaction by dominant sows that impact on stress and possibly reproductive performances.
- Determine the advantages of using feeding stalls, distinct mating stalls, (and the length of stall housing), or mating in the pen (i.e. no mating stall) for optimal insemination rate and reduced risk to recently inseminated sows, and possibly risks to the group as a whole through the expression of sexual behaviour toward other sows.
- Investigate the management of the system from an industry-feasibility point of view (dynamic vs. static group after mating). No research has been conducted on the topic.
- Develop and validate effective and minimally-labour intensive oestrus detection protocols and boar exposure methods to optimize oestrus detection and mating success in a reasonable time-frame after weaning (5 to 6 days after weaning).
- Research on a larger sample size is needed to assess whether aggression and stress effects in group-weaning systems affect farrowing performances and sow productivity.

Acknowledgements

The authors thank Rebecca Woodhouse, Maxine Rice, the Rivalea R&D team, and the staff from Rivalea Module 3 for their help with conducting this project, and Lisbeth Ulrich Hansen for her intellectual input.

8. References

Arey, D. S., and Edwards, S. A. (1998). Factors affecting aggression between sows after mixing and the consequences for welfare and production. *Livestock Production Science*, 56, 61-70.

Ashworth, C.J., and Pickard, A.R. (1998). *Embryo survival and prolificacy*. Pages 303-325 in Progress in Pig Science. Wiseman, J., Varley, M.A., and Chadwick, J.P., eds. Nottingham University Press, United Kingdom.

Bocking, A. D., McMillen, I. C., Harding, R., and Thorburn, G. D. (1986). Effect of reduced uterine blood flow on fetal and maternal cortisol. *Journal of Developmental Physiology*, 8, 237-245.

De Jonge, F.H., Mekking, P., Abbott, K., and Wiepkema, P.R. (1994). Proceptive and receptive aspects of oestrus behaviour in gilts. *Behavioural Processes*, 31, 157-166.

England, D. C., and Spurr, D. T. (1969). Litter size of swine confined during gestation. *Journal of Animal Science*, 28, 220-223.

Fahmy, M. H., and Dufour, J. J. (1976). Effects of postweaning stress and feeding management on return to oestrus and reproductive traits during early pregnancy in swine. *Animal Production* 23, 103-110.

Fisker, B.N. (2003). The importance of rest after insemination. Betydning af ro efter inseminering, meddelelse 586, afp. 581. Available at: http://vsp.lf.dk/Publikationer/Kilder/lu_medd/medd/586.aspx?full=1

Hansen, L.U., Weber, P.M., Schild, S-L., and Hansen, C.F. (2013). Correlation between mounting acivity and leg in juried in sows housed in groups after weaning. Proceedings of the Australiasian Pig Science Association, Melbourne, Victoria, Australia, p. 219.

Hansen, L.U. (2003a) Mating section with individual pens or group-housing. *Løbeafdeling med enkeltdyrsstier eller flokopstaldning - ændret løbestrategi, meddelelse nr. 593*. Available at: http://vsp.lf.dk/Publikationer/Kilder/lu_medd/medd/593.aspx

Hansen, L.U. (2003b) Mating section with individual pens or group-housing with permanent access to feeding/insemination stalls. *Løbeafdeling med enkeltdyrsstier eller flokopstaldning med permanent adgang til æde-/insemineringsbokse, meddelelse 602, afp. 535*. Available at: http://vsp.lf.dk/Publikationer/Kilder/lu_medd/medd/602.aspx

Hansen, L.U. (2000) Mating section with individual pens or group-housing. *Løbeafdeling med enkeltdyrsstier eller flokopstaldning, meddelelse nr*. 493, afp. 417. Available at: http://vsp.lf.dk/Publikationer/Kilder/lu_medd/medd/493.aspx

Hemsworth, P.H., Morrison, R., Verdon, M., and Rice, M. (2013a). Effects of aggressive characteristics of individual sows and mixing strategies on the productivity and welfare of group-housed gestating sows. Final report to the Australian Pork Limited (Project 1C-102), May 2013.

Hemsworth, P. H., Rice, M., Nash, J., Giri, K., Butler, K. L., Tilbrook, A. J., and Morrison, R. S. (2013b). Effects of group size and floor space allowance on grouped sows: Aggression, stress, skin injuries, and reproductive performance. *Journal of Animal Science*, 91, 4953-4964.

Hemsworth, P. H., and Hansen., C. (1990). The effects of continuous boar contact on the estrus detection rate of weaned sows. *Applied Animal Behaviour Science*, 28, 281-285.

Hemsworth, P. H., Barnett, J. L., Hansen, C., and Winfield, C. G. (1986). Effects of social environment on welfare status and sexual behavior of female pigs II. Effects of space allowance. *Applied Animal Behaviour Science*, 16, 259-267.

Hemsworth, P. H., Salden, N. T. C., and Hoogerbrugge A. (1982). The influence of the post-weaning social environment on the weaning to mating interval of the sow. *Animal Production*, 35, 41-48.

Karlberg, K. (1980). Factors affecting post-weaning oestrus in the sow. *Nordisk Veterinary Medicine* 32: 183-193.

Karlen, G. A., Hemsworth, P. H., Gonyou, H. W., Fabrega, E., Strom, D., and Smits, R. J. (2007). The welfare of gestating sows in conventional stalls and large groups on deep litter. *Applied Animal Behaviour Science*, 105, 87-101.

Kemp, B., Soede, N.M., and Langendijk P. (2005). Effects of boar contact and housing conditions on estrus expression in sows. *Theriogenology*, 63, 643-656.

Knox, R. V., Breen, S.M., Willenburg, K. L., Roth, S., Miller, G. M., Ruggiero, K. M., and Rodriguez-Zas, L. (2004). Effects of housing system and boar exposure on estrus expression in weaned sows. *Journal of Animal Science*, 82, 3088-3093.

Kongsted, A. G. (2004). Stress and fear as possible mediators of reproduction problems in group housed sows: a review. *Acta Agriculturae Scandinavica, Section A - Animal Science*, 54, 58-66.

Langendijk, P., Soede, N. M., and Kemp, B. (2000). Effects of boar contact and housing conditions on estrus expression in weaned sows. *Journal of Animal Science*, 78, 871-878.

Mendl, M., Zanella, A.J., and Broom, D.M. (1992) Physiological and reproductive correlates of behavioral strategies in female domestic pigs. *Animal Behaviour*, 44, 1107-1121.

Signoret, J.P., and Du Mesnil du Buisson, F. (1961). Study of the behaviour of the sow during oestrus. Proceedings of the fourth International Congress on Animal Reproduction, The Hague, 2, 171-175.

Pearce, G. P., and Pearce, A. N. (1992). Contact with a sow in estrus or a mature boar stimulates the onset of estrus in weaned sows. *Veterinary Record*, 130, 5-9.

Pedersen, L.J. (2007). Sexual behaviour in female pigs. *Hormones and Behavior*, 52, 64-69.

Pedersen, L. J., Rojkittikhun, T., Einarsson, S., and Edqvist, L. E. (1993). Post-weaning grouped sows: Effects of aggression on hormonal patterns and estrus behavior. *Applied Animal Behaviour Science*, 38, 25-39.

Sommer, B. (1979). Sows in individual pens and group housing—oestrous behaviour, parturition, fertility and damage to limbs. Thesis, Ludwig-Maximilians-Univ., Munich.

Spoolder, H. A. M., Geudeke, M. J., Van der Peet-Schwering, C. M. C., Soede, N. M. (2009). Group housing of sows in early pregnancy: A review of success and risk factors. *Livestock Science*, 125(1), 1-14.

Tilbrook, A. J., and Hemsworth, P. H. (1990). Detection of estrus in gilts housed adjacent or opposite boars or exposed to exogenous boar stimuli. *Applied Animal Behaviour Science*, 28, 233-245.

Turner, A.I., Hemsworth, P.H., and Tilbrook, A.J. (2005). Susceptibility of reproduction in female pigs to impairment by stress or elevation of cortisol. *Domestic Animal Endocrinology*, 29, 398-410.

Turner, A.I., Hemsworth, P.H., and Tilbrook, A.J. (2002). Susceptibility of reproduction in female pigs to impairment by stress and the role of the hypothalamus-pituitary axis. *Reproduction, Fertility, and Development*, 14, 377-391.