RESEARCHREPORT

ANIMAL WELFARE

Title: Protecting low ranking sows in group-housing systems – **NPB 11-044**

Investigators: Y. Z. Li, Lihua Wang, and L. J. Johnston

Institution: West Central Research and Outreach Center, University of Minnesota, Morris, MN

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Industry Summary

Background: In group-housing systems, low-ranking sows are usually defeated and injured by high ranking sows. This results in low-ranking sows becoming fearful of further conflicts when attempting to obtain feed which leads to inadequate feed intake and poor body condition. Poor body condition and injuries of low-ranking sows represent an important concern for animal welfare and economics of group-housing systems. By understanding and protecting low-ranking sows, we will be able to eliminate individuals with poor body condition and severe injuries, and consequently improve well-being and performance of sows in group-housing systems.
Objectives: The objectives of this project were to: 1. identify characteristics of low-ranking sows in group housing systems; 2. assess effects of group size on well-being and performance of low-ranking sows; 3. determine effects of feeding stalls on well-being and performance of low-ranking sows; 4. assess effects of social rank of sows on well-being and performance of offspring.
Procedures: The project consisted of two studies conducted at two sites: the University of Minnesota's West Central Research and Outreach Center (WCROC), and a commercial farm with a 5,000-sow unit. At the WCROC, 150 sows (Landrace x Yorkshire, parity 1 to 9) that were group-housed with individual feeding stalls were used to accomplish *objective 1, 3, and 4*. Sows were assigned to pens (15 sows/pen, 2.2 m^2/sow of floor space) at weaning. The control pen allowed sows to access feeding stalls only for feeding during the initial 48 h of mixing. The treatment pen allowed sows to access feeding stalls continuously. From the third day of mixing through the remainder of the gestation period, all sows in both control and treatment pens had continuous access to feeding stalls. To determine sow rank and stall usage, fighting among sows and sow staying in stalls were recorded by video-cameras for 48 h after mixing. Social rank was determined for each sow based on outcomes (wins vs. losses) of fights. Skin lesions were assessed before and 48 h after mixing, and before farrowing. Fear response, salivary cortisol concentrations, and heart rates were measured 5 weeks after mixing. To examine effects of sow rank on offspring, high ranking sows and low ranking sows farrowed in a group-farrowing system where 8 sows farrowed in individual pens and shared a communal area in each room. Sows and piglets commingled into a large group within each room when pens were removed at 10 d after farrowing. Farrowing performance, aggression among piglets at farrowing pen removal, and weight gain of piglets during lactation were recorded. At the commercial farm site, 152 confirmed pregnant sows (35 d post-mating, Camborough, PIC USA, parity 1 to 6) were allocated to 4 large pens (26 sows per pen) and 8 small pens (6 sows per pen) to accomplish *objective 2*. Both large and small pens provided the same floor space allowance (1.5 m^2 per sow) and sows were fed on the

solid portion of partially slatted floors. Aggression among sows at mixing and during the first two meals after mixing was recorded, and social rank was determined for each sow based on outcomes of aggression. Skin lesions were assessed at 24 after mixing and before farrowing. Salivary cortisol concentrations were measured at 5 weeks after mixing. Sows farrowed in farrowing crates and the reproductive performance of sows was recorded.

Findings: Results from the WCROC demonstrated that low ranking sows were younger (parity 1.5 vs. 3.9) with lower body weight (221 vs. 242 kg) at mixing than high ranking sows. Low ranking sows fought less frequently (40 vs. 60 fights/sow/6h), and lost more fights (76 vs. 19% of total fights) than high ranking sows, but sustained similar injuries caused by fighting as high ranking sows. Low ranking sows were more fearful at 5 weeks after mixing, indicating compromised welfare. In addition, low ranking sows farrowed smaller litter sizes (12.0 vs. 13.4 total born, 11.8 vs. 12.8 born alive) compared with high ranking sows, which may be attributed to poor welfare. The smaller litter sizes farrowed by low ranking sows were associate with fewer piglets dead (1.2 piglets/litter) in the group-farrowing system. As a result, low ranking sows did not wean smaller litter sizes (9.0 vs. 8.4) than high ranking sows. Piglets that were born to low ranking sows were similar in birth weight and weaning weight to piglets born to high ranking sows, indicating that maternal social rank did not affect the growth performance of offspring during the lactation period. Piglets born to low ranking sows fought frequently as and won more fights than piglets born to high ranking sows at 10 d of age, indicating that the behavioral characteristics of low ranking sows did not reflect on offspring. No difference in condition scores, backfat thickness, weight gain during gestation, cortisol concentrations, heart rates, and farrowing rates between high ranking and low ranking sows was observed.

On average, sows in pens with continuous access to feeding stalls spent 10% of their time in stalls during the first 10 h after mixing. Low ranking sows spent more time (13.4 vs. 5.8%) in stalls than high ranking sows. The difference in stall usage between low ranking and high ranking sows was more significant during the initial 4 h after mixing (27.2% vs. 6.9% of total observation time). This suggests that low ranking sows use feeding stalls as hiding spaces to avoid attacks from unfamiliar sows when fighting was intense. As a result, sows in pens with continuous access to feeding stalls fought less (38 vs. 50 fights/sow/6h), and low ranking sows sustained fewer skin lesions than their counterparts in control pens. These results suggest that access to feeding stalls during the mixing period improved the welfare of low ranking sows, as indicated by reduced injuries caused by fighting.

Results from the commercial farm confirmed the finding at the WCROC that low ranking sows fought less frequently and lost more fights than high ranking sows at mixing, but had similar skin lesions caused by fighting as high ranking sows. Low ranking sows and high ranking sows entered gestation pens with similar body weights and condition scores, but low ranking sows gained less weight (33 vs. 50 kg), resulting in lower body weight (251 vs. 268 kg) and poor conditions before farrowing than high ranking sows. This suggests that low ranking sows were less competitive for feed than high ranking sows in the group housing system with floor feeding. In addition, low ranking sows sustained more skin lesions than high ranking sows before farrowing, which might be attributed to fights received by low ranking sows during feeding. Small groups appear better than large groups for sow welfare and performance because all sows had fewer skin lesions and higher farrowing rates (97.9 vs. 87.4%) in small pens than in large pens. Consistent with the study at the WCROC, we did not observe difference in cortisol concentrations, condition scores of sows, litter sizes and litter weight weaned between low ranking and high ranking sows. We also did not observe difference in litter size farrowed between low ranking and high ranking sows, which was inconsistent with the results of the WCROC study.

Conclusions: Low ranking sows were more fearful, fought less frequently and lost more fights than high ranking sows in group-housing systems. Low ranking sows were less competitive for feed in the group housing system with floor feeding and had poor welfare compared with high ranking sows, as indicated by more skin lesions, less weight gain, and lower body weight before farrowing. Small group size appears better than large group size for sow well-being and performance because sows in small groups had fewer skin lesions and higher farrowing rate. In the group-housing system with individual feeding stalls, low ranking sows used stalls as hiding spaces to escape from fighting during the initial mixing period, which reduced skin lesions caused by fighting and improved the welfare of low ranking sows. Sow rank did not affect the growth performance of their piglets during lactation, and behavioral characteristics of low ranking sows did not reflect on their offspring.

Key Words: housing, social rank, sow, welfare

Contact details: Yuzhi Li, yuzhili@morris.umn.edu, office: 320-589-1711

Abstract

Two studies were conducted to evaluate strategies to protect low ranking sows in group-housing systems. In the first study, the strategy of using feeding stalls to protect low ranking sows was examined at the University of Minnesota's Research and Outreach Center. One hundred and fifty sows (Landrace x Yorkshire, parity 1 to 9) that were housed in pens (15 sows/pen, 2.2 m^2/sow) with individual feeding stalls were used. Sows were mixed in pens at weaning. The control pen allowed sows to access feeding stalls only for feeding during the initial 48 h of mixing, and the treatment pen allowed sows to access feeding stalls continuously. From the third day of mixing through the remainder of the gestation period, all sows had continuous access to feeding stalls. In the second study, the effect of group size on the well-being and performance of low ranking sows was evaluated on a commercial 5,000-sow farm. One hundred fifty pregnant sows (Camborough, PIC USA, parity 1 to 6) were allocated to 4 large pens (26 sows/pen) and 8 small pens (6 sows/pen) at 35 d post-mating. Both large and small pens provided the same floor space allowance (1.5 m^2 per sow) and sows were fed on the solid portion of partially slatted floors. In both studies, aggressive interactions among sows after mixing were recorded, and a rank index was calculated for each sow based on outcomes of aggression. Sows were categorized as high, middle and low ranking sows according to their rank indices. Data were analyzed using the Mixed and Glimmix model of SAS. *Characteristics of low ranking sows:* Low ranking sows were younger (parity 1.5 vs. 3.9, SE = 0.23; P < 0.001) with lower body weight (221 vs. 241 kg, SE = 5.0; P < 0.001), fought less frequently (40 vs. 60 fights/sow/6h, SE = 3.8; P < 0.001), lost more fights (76 vs. 19%, SE = 4.4; *P* < 0.001) at mixing, and more fearful (*P* = 0.01) than high ranking sows. In the group housing system with floor feeding, low ranking sows sustained more skin lesions before farrowing (*P* = 0.01), and gained less weight (33 vs. 50 kg, SE = 5.6; P < 0.001) during gestation, resulting in lower body weight (251 vs. 268 kg, SE = 6.0; P = 0.01) and poor condition (2.9 vs. 3.0 SE = 0.05; P = 0.08) before farrowing than high ranking sows. Body conditions and back fat thickness at mixing, cortisol concentrations, and heart rates were not associated with social rank of sows. *Effects of group size on the well-being and performance of low ranking sows:* Within the group housing system with floor feeding, sows in small groups had lower skin lesion scores after mixing (11.8 vs. 14.6, SE = 1.0; P < 0.001) and before farrowing (5.6 vs. 8.3, SE = 0.63; *P* = 0.01), and had higher farrowing rates (97.9 vs. 87.4%, Chi-square = 4.2; P = 0.40) than sows in large pens, indicating that small groups were better than large groups for the well-being and performance of sows. *Using feeding stalls to protect low ranking sows:* Low ranking sows used the feeding stalls more frequently (27.2% vs. 6.9% of observation time, SE = 4.75; P < 0.001) than high ranking sows during the initial 4 h after mixing when fighting was intense, suggesting that low ranking sows used feeding stalls as hiding places to avoid attacks from unfamiliar sows. Continuous stall access reduced fighting frequency (37.9 vs. 49.9 fights/sow/6h, SE = 3.1; P < 0.001) in the pen, and consequently, reduced skin lesions (10.5 vs. 12.6, SE = 0.68; P = 0.01) of low ranking sows. *Well-being and performance of offspring:* No significant difference (all P > 0.23) was observed in birth weight (1.6 vs. 1.5 kg, SE = 0.04), weaning weight (9.3 vs. 8.8 kg, SE = 0.39), and number of piglets weaned (9.0 vs. 8.4, SE = 0.46) between piglets that were born to low ranking sows and high ranking sows. Piglets born to low ranking sows fought frequently as (1.7 vs. 2.1 fights/pig/2h, SE = 0.38) and won more fights (23.1 vs. 18.6%, SE = 2.27; P = 0.01) than piglets born to high ranking sows when mixed with other litters. These results suggest that maternal social rank did not affect the growth performance and behavior of offspring during lactation. In conclusion, the well-being of low ranking sows was comprised in the group-housing with floor feeding, as indicated by less weight gain during gestation, lower body weight and more skin lesions at farrowing compared with high ranking sows. Small group size appears better than large group size for sow well-being and performance because sows in small groups had fewer skin lesions and higher farrowing rate. In the group-housing system with individual feeding stalls, low ranking sows used feeding stalls as hiding places to escape from fighting during the initial mixing period, which reduced skin lesions of low ranking sows. Behavioral characteristics of low ranking sows did not reflect on their offspring, and maternal social rank did not affect the

growth performance of piglets during lactation.

Introduction

Animal welfare concerns have led to gestation stalls being banned in the EU countries and several states in the United States. When group housing of gestating sows is required by regulations, comparison between gestation stalls and group-housing systems is no longer an interest to swine producers. Instead, producers are looking for information on how to manage sows in group-housing systems in order to successfully transition from gestation stalls to group housing systems.

A variety of group-housing systems exists, and the welfare of sows in different group housing systems can differ (Task Force Report, 2005). To ensure the welfare and performance of sows, the minimal requirement for group housing systems is to be able to control individual feed intake and alleviate aggression during mixing and feeding (Gonyou, 2005). Therefore, the feeding system becomes an essential factor to the success of group-housing gestating sows. Among the feeding systems currently available for group-housed sows, feeding stalls which can be manually locked when sows are eating can control individual feed intake, allow sows to eat simultaneously, and eliminate aggression during feeding. In addition, continuous access to stalls during mixing may protect sows from aggression, and reduce injuries caused by fighting, which may help the formation of dominant hierarchy in a group (Barnett et al., 1993). Rioja-Lang et al. (2013) reported that low ranking sows spent more time in free access stalls than high ranking sows, suggesting that low ranking sows use the stalls to prevent threats and attacks from high ranking sows. However, Petherick et al. (1987) pointed out that sows retreating into stalls might be more vulnerable to bites to the rear and vulva regions by pursuing attackers when the stalls cannot automatically close and lock the sow in. So, the benefit of using feeding stalls without automatic gates to protect sows from being attacked during mixing is uncertain.

Within a given group-housing system, the welfare level of individual sows can vary greatly. Social rank is a major factor that affects the welfare level of an individual sow in a group. Low ranking sows usually suffer poor welfare in a group, as indicated by more injuries caused by aggression (O'Connell et al. 2003). After losing most fights during mixing, low ranking sows become fearful of further conflicts when attempting to obtain feed which can lead to inadequate feed intake (Kongsted, 2006), less weight gain and poor body conditions (Kranendonk et al., 2007), smaller litter sizes farrowed (Hoy et al., 2009a) and lighter pigs weaned (Kranendonk et al., 2007). These problems become more predominant when group-housed sows are fed on floors.

Group size may affect low-ranking sows in group-housing systems (Turner et al., 2001). In small groups, low-ranking sows are dominated by fewer sows, but have limited space to hide or escape from aggression and threats by high ranking sows. In contrast, low-ranking sows in large groups have more space to escape, but also encounter more dominant sows. The effect of group size on welfare and performance of low ranking sows have not been assessed. By understanding and protecting low-ranking sows, we will be able to eliminate individuals with poor body condition and severe injuries, and consequently improve well-being and performance of sows in group-housing systems.

Objectives

1. To identify characteristics of low-ranking sows in group housing systems.
2. To assess effects of group size on well-being and performance of low-ranking sows.
3. To determine effects of feeding stalls on well-being and performance of low-ranking sows.
4. To assess effects of social rank of sows on well-being and performance of offspring.

Materials and Methods

The Institutional Animal Care and Use Committee of the University of Minnesota reviewed and approved the experimental protocol for this project. Two studies were conducted to achieve the objectives.

Study One

The first study was conducted at the University of Minnesota's West Central Research and Outreach Center in Morris, MN during December, 2011 through March, 2013 to accomplish objective 1, 3, and 4. Gestating sows (Yorkshire × Landrace, parity 1 to 9) were group-housed in a straw-bedded hoop barn as described previously (Li et al., 2012). The gestation barn had 4 pens with 15 sows per pen. Each pen was equipped with individual feeding stalls and a bowl drinker with 2 drinking spaces on concrete floors. The feeding stalls (1.88 m × 0.46 m × 1.22 m in height) were equipped with rear gates which were opened or closed simultaneously with a manually controlled lever. Other areas in the pen (7.62 m × 4.39 m) were bedded with straw, providing bedded space allowance of 2.2 m^2/sow. Every 10 wks, 30 sows were weaned into two pens and mated within 5 days. Sows were provided 2.5 kg once daily between 0700 h and 0900 h of a corn-soybean meal based gestation diet formulated to meet or exceed NRC (1998) nutritional requirements for gestating sows. Within each breeding cohort, 16 sows (8 high ranking and 8 low ranking) farrowed in a group-farrowing barn as described previously (Li et al., 2010) and the reminder of the cohort farrowed in individual crates in a confinement-farrowing barn. In the group-farrowing barn, 8 sows from one gestation pen were housed in each of two identical rooms (9.8 m × 11.0 m) where they farrowed in bedded, individual pens, and shared 2 feeders (4 feeding spaces each) and 2 cup drinkers in a communal area. Farrowing pens were removed at 10 (± 2.3 SD) d after farrowing so that sows and their piglets within each room mingled in a large group on bedded floors between pen removal and weaning at 33 (± 2.3 SD) d after farrowing. Sows in the confinement barn were weaned at the same time as sows in the bedded, group-farrowing barn. After weaning, sows were moved to the gestation hoop barn where they were bred and started a new breeding cycle.

To test whether stalls can be used by sows as hiding spaces from fighting during the initial period of mixing, two pen treatments were generated: pens with COUNTINUOUS ACCESS to stalls and pens with LIMITED ACCESS to stalls. In continuous access pens, sows had access to feeding stalls continuously for the entire gestation period. During feeding time, sows were locked in feeding stalls for one hour to ensure that all sows had enough time to consume their daily rations. Then, stalls were opened and remained open until the next feeding time. In limited access pens, feeding stalls were only used for feeding during the first 2 days of mixing. Sows were locked in stalls for 1 h during feeding. Then, sows were locked out and maintained in the bedded area. From the third day through the remainder gestation period, all sows had free access to feeding stalls.

Five breeding cohorts of sows were used at 10-wk intervals. Within each breeding cohort, two groups of 15 sows were allocated to and mixed in two treatment pens after weaning. In total, 150 sows were used for data collection, with 75 sow assigned to each treatment. All sows used in the study had been housed in the group-housing system during their previous gestation. As gilts were housed separately, they were not included in the study.

At allotment, sows were sorted by parity and familiarity. Unfamiliar is defined as sows that have not been housed in the same group at least during the last 4 wks (Spoolder et al., 1996; Hoy and Bauer, 2005). In this particular study, unfamiliar sows originated from different farrowing rooms (housing during previous gestation was not considered in defining familiarity). Each pen consisted of 4 groups of 3 to 4 sows that originated from each of three group-farrowing rooms and the confinement farrowing room. The frequency composition by parity and the proportion of unfamiliar dyads (unfamiliar pairs of sows) was balanced between two treatment pens.

All sows were mixed between 9:00 h and 11:00 h in their designated gestation pens on the day of weaning, and bred within a window of 5 days in feeding stalls or in the pens. Sows remained in the gestation pens until about 110 d of gestation, and then were moved to farrowing barns.

Data collection

All sows were weighed individually before mixing into gestation pens. Meanwhile, backfat thickness was measured and body condition was assessed. Back fat thickness was measured using an ultrasonic scanner (Lean-meater, Renco; Minneapolis, MN.) at the P2 position which was 65 mm down the left or right side from the midline, at the level of the head of the last rib, according to the SOP of the NSW Government (2011). The method to assess body condition followed that of Coffey et al. (1999) on a 1-5 scale, which has been adopted by the U.S. National Pork Board in the Pork Quality Assurance (PQA) Plus program.

Social rank and aggression at mixing

To determine dominance hierarchy, aggressive interactions among sows after mixing were video-recorded. All sows in each pen were marked with large numbers on their backs for individual identification under cameras. Two digital cameras (Hi-Res Bullet Cams 2505, Sony, Taiwan) were installed in each pen, one on the back wall and another on the front wall of the pen. The cameras were connected to a computer equipped with a time-lapse DVR device and video-recording software (Geo Vision Multicam Digital Surveillance System V8.2; USA Vision Systems Inc, Irvine, CA). Video-recording began immediately upon completion of mixing at a speed of 12 frames/s and continued for 48 h. Aggressive interactions among sows during the initial 6 h after mixing were registered from the video by a trained observer. Aggressive interactions were classified as parallel and inverse parallel pressing, biting and knocking, and threat (O'Connell et al., 2003; Ison et al., 2010). Parallel and inverse parallel pressing was defined as sows that stand side-by-side and push hard with the shoulders against each other, generally performed with frequent bites. Biting and knocking were defined as a sow delivering rapid bites or knocks with the snout against the head or body of the receiver. Threat was defined as a sow displayed offensive gestures to another sow without any physical contact and resulted in another sow changing direction to avoid the offensive sow. Videos were viewed continuously, and aggressive interactions, outcomes (wins, losses, and ties) of aggressive interactions, and individual sows that involved in were registered. A 15 × 15 winner-loser matrix (Hoy and Bauer, 2005) was used for recording the number of wins and losses for each sow. Based on the number of wins and losses, a rank index (RI) was calculated for each sow using the equation:

$$\mathrm{RI} = [(\mathrm{S} \times P_s) - (N \times P_n)]/[(\mathrm{S} + \mathrm{N}) \times (\mathrm{n} - 1)]$$

S = number of wins, Ps = number of partners the sow had defeated, N = number of losses, Pn = number of partners the sow was defeated by, n = total number of sows in the pen (Hoy et al., 2009b). Based on the rank indices, each sow in a pen was ranked in order from 1 to 15, with rank 1 as the highest (most dominant) and rank 15 as the lowest (most subordinate) rank. For further data collection, sows with rank 1 to 5, 6 to 10, and 11 to 15 was categorized as high, middle, and low rank, respectively.

Stall usage

To investigate whether sows used feeding stalls as hiding spaces to avoid aggressive interactions during mixing, stall usage by sows in continuous access pens was recorded by the same video-recording system as for aggression interactions among sows. Videos for the initial 10 h after mixing were analyzed by instantaneous scan sampling. Each pen was scanned at 5-min intervals for a total of 120 times. At each scan, individual sows that stayed in stalls were identified and registered, from which time spent in stalls by each sow was calculated as percentage of the observation time according to the method described by Martin and Bateson (1993).

Fear response

Fear responses of sows were tested at 5 wks after mixing using the method of 'return to human in home pen test' as described by Scott et al. (2009). During the test, sows remained in their home pen in the normal farm situation. The test was carried out as a 3-step procedure: Step 1: the observer, wearing stockperson's overalls, walked around the perimeter of the pen at a steady pace alerting the sow to his presence. Then, the observer moved to the 'start' position of 0.5-1.0 m away from the test sow, and remained motionless in a relaxed posture with hands by his sides for 10 seconds. Step 2: the observer approached the head end of the test sow, squatted down, and remained motionless for 10 seconds. Step 3: the observer attempted to touch the sow between the ears and maintained contact for 10 seconds. The behavioral responses of the sow were evaluated using a scale of 0 to 6 (with 0 being the most fearful and 6 being the least fearful) as follows: 0 = the sow withdrew from the start position (Step 1), 1 = the sow withdrew initially but then approached the observer, 2 = the sow withdrew and remained withdrawn while the observer crouched down in front of the sow (Step 2), 3 = the sow withdrew initially but then approached the observer, 4 = the sow withdrew when the observer attempted to touch her between the ears and stayed withdrawn (Step 3), 5 = the sow initially withdrew, but then approached the observer, 6 = the sow allowed the observer to touch her between the ears without any withdrawal response. The test was conducted in both treatment pens on the same day between 1:00 h to 3:00 h. Within each pen, the order of assessment for an individual sow was determined randomly. All sows were assessed by one observer and one recorder.

Skin lesions

All sows were assessed for skin lesions before and 48 h after mixing, and before being moved for farrowing. Skin lesions were assessed using the methodology of Hodgkiss et al. (1998), which combines scores of 0 to 3 from 12 surface regions of the body: two ears, snout, two shoulders, two flanks, two hindquarters, top of the back, tail, and vulva. The scoring system is: 0 = No injury (skin unmarked: no evidence of injury from agonistic behavior), 1 = Slight injury (< 5 superficial wounds), 2 = Obvious injury (5-10 superficial wounds and /or <=3 deep wounds), 3 = Severe injury (> 10 superficial wounds, and /or > 3 deep wounds).

Salivary cortisol concentrations

Salivary samples were collected on 40 focal sows 5 wks after mixing, including 20 low ranking and 20 high ranking sows from both treatment pens. The samples were collected using 'Salivette' (Sarstedt Ltd, Germany) which contained a cylindrical piece of cotton fitted inside a plastic tube. The cotton was secured to 150 cm long dental floss and placed into the mouth of the sow with minimal disturbance to the sow. The sow was allowed to chew on the cotton until it was saturated with saliva. To avoid cortisol level being elevated by handling stress, each saliva sample was collected within 3 min of approaching the sow. Saliva was removed by centrifugation at 3000 rpm for 5 min, and frozen at -20°C for subsequent analysis. Cortisol concentration was determined by radioimmunoassay according to the manufacturer's instructions.

Study Two

The second study was conducted on a commercial farm with a 5,000-sow breeding-to-wean unit between September, 2009 and May, 2011 to accomplish objective 2. Four large pens and eight small pens that were retrofitted from gestation stalls were used (see Johnston and Li, 2013 for details about pen configurations). Large pens (5.5 m × 7.3 m) housed 26 sows per pen, and small pens (5.5 m × 1.7 m) housed 6 sows per pen on partially slatted floors. The solid areas in each large pen were divided by short fences (1.8 m) into 6 smaller areas so that sows could be fed and rest in smaller sections and in smaller subgroups. Large pens were equipped with four bowl drinkers and small pens had one bowl drinker. Floor space allowance was 1.5 m^2 per sow in both large and small pens. All sows were provided 2.5 kg of a corn-soybean meal based gestation diet formulated to meet NRC (1998) nutritional requirements for gestating sows. The daily ration was delivered in two portions, with two thirds of the ration delivered at 0600 h and one third delivered at 1200 h. Feed was dropped on the solid portion of the floor from the existing feeder lines so that each sow had a feed pile dropped. Temperature in the room was controlled by ventilation fans and heaters to achieve temperature as near as possible to the thermoneutral zone for gestating sows. Light period was 9 h starting from 0600 h with emergency lights on during the dark period. Room temperature, feeders, drinkers, and animal health were checked twice daily in the morning and afternoon. When any sows were removed from the study, the reason for removal was recorded.

Sows (parity 1 to 6; Camborough, PIC USA) were housed in gestation stalls during their previous gestation (no gilts were included in this study). Then, sows farrowed in individual stalls, and cross-fostering was conducted within 48 h after farrowing as per routine commercial practice on the farm. Sows were weaned at about 21 d after farrowing. At weaning, all sows were moved to stalls where they were mated and remained in stalls until confirmation of pregnancy by ultrasound at about 35 d after breeding. Pregnant sows from the same breeding cohort were sorted by parity and by body size (large or small determined by visual appraisal). Parity was categorized as parity 1, parity 2, and parity 3 or greater (parity 3+) at breeding. Within each category of parity and size, sows were assigned randomly to one large pen and two small pens. Sows remained in their designated housing treatment until about d 109 of gestation when they were moved to farrowing stalls. This procedure was repeated for 4 contemporary breeding groups at 4 to 6 wk intervals. In total, 152 sows were used with 104 sows being assigned to 4 large pens and 48 sows to 8 small pens.

Data Collection

The data collection period started from the time that sows were allocated to the study after pregnancy confirmation until being mated for the next reproductive cycle after weaning their litters. All sows were weighed individually at allocation to pens, at entry to farrowing rooms on d 109 of gestation, and at weaning. Changes in body weight during gestation and lactation were calculated. Body condition was assessed for each sow at allocation to gestation pens and before being moved for farrowing. Standard production data were collected for each sow at farrowing and at weaning from the existing on-farm computerized record system. These data included: number of sows farrowed, litter size farrowed (number of total born, born alive, stillborn, and mummified for each litter), and litter size and litter weight at weaning. Farrowing rate was calculated based on the number of sows farrowed as percent of sows assigned to the study after pregnancy confirmation. In addition, the number of sows expressing estrus after weaning and the wean-to-estrus interval were also recorded.

Social rank and aggression at mixing

All sows were mixed in pens between 900 h and 1000h. Fighting among sows at mixing and during the first two meals after mixing was observed continuously by live observation. Fighting included pressing (parallel and inverse parallel), biting and knocking as defined in the first study. Sows were identified individually with colors and patterns painted on their backs. To record fighting at mixing, the observations started immediately after mixing and continued for 2 h. The first feeding after mixing occurred at noon on the mixing day, and the second feeding was at 6:00 h in the next morning. Observations during feeding were conducted for the entire feeding period, starting from the time when feeder lines were turned on to drop feed until all feed was consumed by the sows. The number and outcomes of fights that each sow involved in were registered. Rank indices (RI) were calculated for each sow using the same method as in the first study. Based on rank indices, sows in each pen were categorized as high, middle or low ranking. In large pens, 8 sows were categorized as high, 10 sows as middle, and 8 sows as low ranking, and in small pens, 2 sows were categorized as high, middle, or low ranking, respectively.

Skin lesions

To evaluate injuries caused by aggression, skin lesions were assessed for each sow at 24 h after mixing and before farrowing, using the same method as in the first study.

Salivary cortisol concentrations

Salivary samples were taken from 16 sows (8 high ranking and 8 low ranking sows) in large pens, and 8 sows (4 high ranking and 4 low ranking sows) in small pens at 24 h and 5 wks after mixing for cortisol analysis using the same method as in the first study.

Data analyses

Data were analyzed using the SAS software package (SAS Institute Inc., Cary, NC; 2005). All data were tested for normal distribution by using the Univariate Procedure of the SAS. Data that were not distributed normally were transformed using logarithm ($X' = \text{Log10}(X + 1) + 0.5$) to achieve normal distribution (Zar, 1999). Since the incidence of skin lesions before mixing and before farrowing for sows in the first study was rare, the data were excluded from the analysis. The Frequency procedure with Chi-square test was used to examine effect of pen treatment on number of sows that farrowed. The Proc Mixed model was used to analyze the data of body weight, backfat thickness and cortisol concentration, and the Proc Glimmix model was used to analyze the remainder data. Within the Glimmix procedure, the Poisson regression model was used for analysis of count data, and the Gaussian Model was used for analysis of continuous data. For all data analysis, the models included social rank, pen treatment (which was stall access for the first study, and group pen size for the second study), and their interactions as fixed effects. Replicate (breeding group) served as the random effect and individual sow was the experimental unit. To adjust parity effect, parity was included as covariance in the Mixed and Glimmix models. Differences between means were tested by PDIFF with the Tukey adjustment for multiple comparisons. Significant differences between means were identified at $P < 0.05$ and trends at $P < 0.10$.

Results

Characteristics of low ranking sows

In the first study, low ranking sows were younger (parity 1.5 vs. 3.9, P < 0.001; Table 1), and lighter at mixing (221 vs. 241 kg, P < 0.001) and before farrowing (263 vs. 278 kg, P = 0.05) compared to high ranking sows. Low ranking sows fought less frequently (40 vs. 60 fights/sow/6h, P < 0.001; Table 2), and lost more fights (76 vs. 19%, P < 0.001) at mixing than high ranking sows. Although fighting less frequently, low ranking sows had similar lesion scores (P > 0.10) as high ranking sows at 48 h after mixing, suggesting that each fight caused more damage to low ranking sows. Being defeated during the initial mixing period resulted in low ranking sows becoming more fearful, as indicated by lower fear scores (2.1 vs. 3.7; P = 0.01) compared with high ranking sows after a stable social group formed at 5 wks after mixing.

Low ranking sows farrowed smaller litter sizes (12.0 vs. 13.4 for total born, 11.8 vs., 12.8 for live born, Table 4) than high ranking sows. The smaller litter size farrowed by low ranking sows was associated with fewer dead piglets (2.8 vs. 4.0 pigs/litter, P < 0.05) during lactation in the group-farrowing system. As a result, low ranking sows did not wean smaller litters (9.0 vs. 8.3; P = 0.43) compared with high ranking sows. Body conditions, backfat thickness (Table 1), cortisol concentrations (Fig. 3), and heart rate (Fig. 4) were not associated with social rank of sows.

Effect of group size on low ranking sows

In the group-housing system with floor feeding, group size did not affect number of fights that each sow involved in (Table 6). However, sows in small groups had lower skin lesion scores than sows in large pens at both 24 h after mixing (P < 0.001) and before farrowing (P = 0.01), suggesting that small pens are better than large pens for sow welfare in the group housing system studied. An interaction of group size and social rank was observed for skin lesion at 24 h after mixing, which was resulted from lower lesion score for high ranking (P < 0.01) and low ranking sows (P = 0.10; Fig 5) in small pens than their counterparts in large pens. In addition, the low lesion scores was associated with lower cortisol levels (P = 0.10; Fig. 6) for low ranking sows in small pens compared with their counterparts in large pens.

Group size did not affect weight gain of sows. Sows in small groups were younger (parity 2.0 vs. 3.3, P < 0.001) with lighter weights (207 vs. 227 kg, P < 0.001) and lower condition scores (2.7 vs. 2.9, P < 0.05) at entering gestation pens, and remained lighter weight before farrowing (P = 0.01) and at weaning (P = 0.01) the subsequent litters compared with sows in large groups. However, sows in small pens had higher farrowing rates (97.9 vs. 87.4, P = 0.04; Table 7) than sows in large pens. Consistent with skin lesion scores, the greater farrowing rates were resulted from higher farrowing rates for high and low ranking sows in small pens compared with their counterparts in large pens. In addition, sows in small pens returned to estrous sooner (4.7 vs.6.1 d, P = 0.01) after farrowing than sows in large pens, which was resulted from shorter wean-to-mate intervals for high ranking sows and middle ranking sows than their counterparts in large pens. Neither group size nor social rank affected litter size farrowed, weaned or litter weight weaned.

Similar to the results in the first study, low ranking sows in the second study fought less frequently (9 vs. 21 fights/sow/2h at mixing, P = 0.01; Table 6) and lost more fights (89 vs. 32%, P < 0.001) than high ranking sows at mixing, but they sustained similar skin lesion scores at 24 h after mixing as high ranking sows. Before farrowing, however, low ranking sows had more skin lesions than high ranking sows (P = 0.01), indicating compromised welfare for low ranking sows.

Low ranking sows were less involved in fighting during the first two meals after mixing (2.3 vs. 3.9 fights/sow, P = 0.01; Table 6), which indicates that low ranking sows were less competitive at feeding than higher ranking sows. This contributed to less weight gain (33 vs. 50 kg, P < 0.001; Table 7) for low ranking sows during gestation compared with high ranking sows. Consequently, low ranking sows had lighter weight (251 vs. 268 kg, P = 0.01) and tended to have poor conditions (P = 0.08) than high ranking sows before farrowing. This further suggests that low ranking sows had compromised welfare in the group housing system with floor feeding.

Using feeding stalls during mixing
On average, sows spent 10% of their time in feeding stalls during the initial 10 h after mixing, with great variation among individual sows (ranging from 0 to 88% of total observation time). Low ranking sows spent 13.5% and high ranking sows spent 5.7% of their time in stalls during the first 10 h after mixing ($P < 0.01$; Table 3), The difference between low ranking and high ranking sows in stall usage were greater during the first 4 h after mixing than during the entire 10 h observation. Low ranking sows spent 27.2% and high ranking sows spent 6.9% of their time in stalls ($P < 0.001$), respectively, during the first 4 h after mixing, which suggests that low ranking sows may use feeding stalls as hiding spaces to prevent aggression from unfamiliar sows when fighting was intense. During the next 4 hours, however, no difference in stall usage was observed between high ranking and low ranking sows. Hiding in stalls reduced the number of fights (38 vs. 50 fights/sow/6 h; Table 1; Fig. 1) at mixing, and consequently, reduced skin lesion scores ($P = 0.01$, Table 1), especially in middle ranking and low ranking sows (Fig. 2) compared with their counterparts in pens with limited access to stalls.

Offspring of low ranking sows
Piglets born to low ranking sows had similar birth weight (1.6 vs. 1.5 kg, SE = 0.04, Table 4) and weaning weight (9.3 vs. 8.8, SE = 0.39) as piglets born to high ranking sows, suggesting that maternal social rank did not affect growth performance of their piglets. At mixing, piglets born to low ranking sows fought frequently as (1.7 vs. 2.0, SE = 0.38; Table 5) and won more fights (23.1 vs. 18.6, SE = 2.27; $P = 0.01$) than piglets born to high ranking sows, indicating that the behavioral characteristics of low ranking sows did not reflect on their piglets.

Discussion

Characteristics of low ranking sows

One of the common characteristics that low ranking sows shared in the two studies was that they fought less frequently at mixing but sustained similar skin lesions as high ranking sows. Fighting among pigs usually causes scratches, resulting in skin lesions. Turner et al. (2009) reported that skin lesions were positively related with the number of fights that sows involved in. In fact, skin lesions caused by fighting is not only related to the number of fights sows involved in, but how sows are involved. Hemsworth et al. (2013) demonstrated that low ranking sows received more fights and high ranking sows delivered more fights in group pens. Sows that received fights more likely get injured. As a result, low ranking sows sustained the same amount of skin lesions as high ranking sows although they were less frequently involved in fighting than high ranking sows. Mendl et al. (1992) reported the same results that low ranking sows fought less frequently but injured similarly to high ranking sows. After frequently being defeated at mixing, low ranking sows were more fearful than high ranking sows. This may help low ranking sows stay away from conflicts with high ranking sows in the group-housing system without competition for feed, which reduced fighting and associated injuries to sows. In fact, in the first study, sows of all social ranks had minimum skin lesions before farrowing, indicating that fighting and associated injuries were subtle after a stable social group is formed. So, in the group housing system with locked individual feeding stalls to prevent competition for feed, social rank of sows did not affect their skin lesions. However, in the second study when sows were fed with the competitive floor feeding system, low ranking sows had more skin lesion than high ranking sows at before farrowing. This may be attributed to competition during feeding, with low ranking sows receiving more attacks than high ranking sows. Hemsworth et al. (2013) reported similar results that low ranking sows had more skin lesions at d 9 and d 51 after mixing in a group-housing system with floor feeding. So skin lesions sustained by low ranking sows after a stable social group is formed depend on the group housing system.

Low ranking sows were more fearful than high ranking sows, and fear can induce chronic stress (Boissy, 1995). An indicator of chronic stress could be adrenal fatigue, resulting in lower baseline of cortisol and blunt adrenal response to stressors. However, we did not observe difference in cortisol concentrations between low ranking and high ranking sows due to large variation. Similarly, Mendl et al. (1992) and Hemsworth et al. (2013) reported no difference in cortisol concentrations between high and low ranking sows. Chronic stress is not well understood and indicators for chronic stress need further investigations.

Low ranking sows gained similar weight as high ranking sows in the group housing system with individual feeding stalls, but gained less weight with floor feeding. This may be because low ranking sows became fear of conflicts and could not compete with high ranking sows, resulting inadequate intake in the competitive floor feeding system. If the feeding system could secure individual sows to consume their rations, the compromised welfare of low ranking sows could be alleviated. These results indicate that welfare of low ranking sows depends on the group housing system (Gonyou, 2005). Hemsworth et al. (2013) reported results similar to ours that low ranking sows gained less weight in a group housing system with floor feeding.

Farrowing performance of low ranking sows in the two studies were not consistent. In the first study, low ranking sows farrowed smaller litter size (both total born and born alive) than high ranking sows. But in the second study, low ranking sows farrowed larger litter size (although not statistically significant in both studies). In a study using more number of sows than ours, Hemsworth et al. (2013) demonstrated that low ranking sows farrowed smaller litter sizes than high ranking sows (although the difference was not statistically significant either).

In the first study, low ranking sows were younger with lighter body weight compared with high ranking sows. But in the second study, we did not found difference in parity or body weight between low ranking and high ranking sows. The discrepancy between the two studies could be resulted from variation in parity and weight. Variation in parity was greater in the first study (parity 1 to 9, with majority sows in the range of parity 1 to 5) than the second study (parity 1 to 6, with majority sows in the rage of parity 2 to 4). It is possible that when there is large variation in parity, younger and lighter sows will become low ranking sows. Hoy et al. (2009b), Arey (1999) and O'Connell et al. (2003) reported that high ranking sows had higher parity and heavier than low ranking sows in groups with large variation in parity. On the other hand, Brouns and Edwards (1994) noted no correlation between body weight and dominance when variation in body weight of sows was low. Likewise, Hemsworth et al. (2013) reported that social rank is determined by fighting styles rather than body weight when using mono-parity sows in their study.

Group size

Theoretically, there may be potential advantages to the welfare of sows in large groups than small groups because large pens provide more space for sows to escape from fighting, resulting in reduced aggression and injuries. However, this was not the case for the current study. We observed that sows in large pens had poor welfare as indicated by more skin lesions than sows in small pens. This could be due to limited floor space allowance combined with floor feeding. Large group sizes combined with high density can result in increased aggression and injuries, due to difficulty to run away from the attackers, as reported by Weng et al. (1998) and Fregonesi and Leaver (2002). Indeed, sows in large groups had more skin lesions at 24 h after mixing and before farrowing in the current study, suggesting more fighting than in small groups both at mixing and during the entire gestation period. We did not observe difference in number of fights among sows between the two groups during the initial 2 h after mixing. This could be because that fighting was intense during the observation period in both groups. In addition, sows in large groups had more fights tied than in small groups, indicating that more fights would be needed for determining dominance hierarchy. It could take longer time for sows in large pens to establish dominance hierarchy in small pens, resulting in more skin lesion at 24 h after mixing. Similar to our results, Barnett et al. (1993) and Barnett et al. (1992) demonstrated that aggression of gilts following mixing was lower in small pens than larger pens. In addition, Gonyou and Lang (2013) reported that the stability of social hierarchy varies with group sizes. Small group (up to 6-8 sows) typically have a very stable hierarchy, positions within the hierarchy rarely change and aggression is minimal. They pointed out that more fighting occurs in larger groups (10-30 animals) than in small groups because of unstable dominant hierarchy. This may explain why sows had higher skin lesion scores before farrowing in large pens than in small pens in our study.

Consistent with low skin lesion scores, sows in small pens also had higher farrowing rate compared with sows in large pens. The difference in farrowing rate was associated with difference in culling rate between the two group sizes. Sows in large pens had greater variation in weight gain, and two sows were culled due to poor body conditions, whereas no sow in small pens was culled for the same reason. The other reasons for sows be culled in large pen were reproductive failure and injuries from fighting. These results further demonstrate that the stable dominance hierarchy of small group size improved welfare and performance of sows in the group housing system with floor feeding, as indicated by reduced skin lesions, reduced culling rate for injuries, and increased farrowing rates.

Using feeding stalls to protect low ranking sows

This study demonstrated that low ranking sows used open feeding stalls more often than high ranking sows during the initial 10 h after mixing. The difference in stall usage between low ranking and high ranking sows was actually resulted from the difference during the initial 4 h after mixing. This time period was coincidence with the time period that fighting was intense for sows after mixing. Sows usually fight frequently and intensively during the initial few hours after mixing and slow down as time passed by (Arey, 1999). In a previous study (Li et al., 2012) conducted using the same sow herd and the same research facility as in the first study, we found that sows fight more frequently and for longer durations during the initial 6 h compared with the remainder period of 72 h after mixing. Similar results have been reported by other researchers (Arey, 1999). It is possible that low ranking sows used stalls simply to get away from attackers when fighting was intense. In fact, when fighting slowed down after the initial first 4 h, low ranking sows spent similar time in stalls as high ranking sows. In contrast, high ranking sows spent constant time in stalls throughout the 10 h of the observation period, regardless of the change in fighting intensity in the pen. Given that feeding stalls were on concrete floors and the other area in the pen was bedded with straw, feeding stalls were not considered an ideal place for sows to rest. Instead of this, low ranking sows still spent significant amount of their time in stalls during the initial period of mixing. This suggests that low ranking sows avoided aggressive interactions by giving up the prime bedded areas. This is supported by results reported by Rioja-Lang et al. (2013) that low ranking sows spent more time than high ranking sows in free access stalls to prevent from being threatened or attacked in communal areas.

Continuous stall access resulted in reduced overall fighting among sows in the pen, and reduced skin lesions of low ranking sows. Skin lesions of high ranking sows were similar between the two pen treatments. These results indicate that stall access during mixing benefit low ranking sows more than high ranking sows. So, this study demonstrated that low ranking sows used feeding stalls as hiding spaces to escape from aggression during mixing, which improve the well-being of low ranking sows in the group housing system.

Well-being of offspring

The current study demonstrated that the behavioral characteristics of low ranking sows did not reflect on their offspring and maternal social rank did not affect the growth performance of piglets. Low ranking sows fought less and lost more fights than high ranking sows. However, piglets born to low ranking sows fought frequently as and won more fights than piglets born to high ranking sows. The heritability of aggression is moderate (h^2=0.17-0.43; Lovendahl et al., 2005; Turner et al., 2009), so maternal aggressiveness could pass on to their piglets. However, aggression in sows can be influenced by their experience and other sows in the group. Hemsworth et al. (2013) demonstrated that aggression in sows varies from parity to parity, suggesting that previous experience and penmates affected aggression of sows. When a low ranking sow realized that she could not win the fight from her experience, she might avoid fighting, resulting in fewer fights involved. These experiences cannot be passed on to offspring so that piglets born to low ranking sows fought no less than other piglets. In our study, piglets were mixed at 10 days of age. At this age, piglets from different litters interacted with little aggression. Fights were short and many fights did not have clear wins or losses. So, the dominancy hierarchy in these piglets may be not clear as in sows. Similar results have been reported by Petersen et al. (1989) and Pitts et al. (2000). Nevertheless, these results suggest that the behavioral characteristics of low ranking sows did not reflect on offspring. In addition, we did not find the effect of maternal social rank on growth performance of offspring during the lactation period in the current study. This disagrees with some previous studies. For example, Kranendonk et al. (2007) reported that the low ranking sows farrowed and weaned lighter pigs than high ranking sows. We observed the opposite that low ranking sows farrowed and weaned slightly heavier pigs than high ranking sows due to the smaller litter size farrowed by low ranking sows. Due to the group-farrowing system used in the current study, the growth performance of piglets during lactation was affected by their ability to compete at nursing. From the observation on aggression among piglets at mixing, we expected that piglets born to low ranking sows should have at least similar competitive ability as piglets born to high ranking sows. So piglets from low ranking sows should have obtained as much milk, resulting in similar growth rate as piglets from high ranking sows.

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Table 1. Effects of stall access and social rank on body weights and conditions of gestating sows in a group housing system with individual feeding stalls

	Stall Access[1]		Pooled	Social Rank[2]			Pooled	P-value		
Item	Limited	Continuous	SEM	High	Middle	Low	SEM	Stall access	Social rank	Interaction
Number of sows assigned	75	75		50	50	50				
Number of sows farrowed	57	58		36	40	39				
Farrowing rate, %[3]	74	76	-	72	80	78	-	0.85	0.67	-
Parity	2.6	2.4	0.19	3.9 [a]	2.7 [b]	1.5 [c]	0.23	0.50	<0.001	0.55
Weight, kg										
At mixing (wt1)[4]	228	230	4.5	241[a]	223[b]	221[b]	5.0	0.57	<0.001	0.26
Before farrowing (wt2)[5]	271	271	3.8	278[a]	269[ab]	263[b]	4.8	0.82	0.05	0.41
At weaning (wt3)[6]	244	238	5.3	248	235	240	6.5	0.39	0.37	0.59
Change in weight, kg										
Gestation (wt2-wt1)	42	37	6.0	33	46	40	6.9	0.39	0.25	0.76
Lactation (wt3-wt2)	-25	-26	3.0	-23[ef]	-32[e]	-22[f]	3.6	0.88	0.06	0.99
Back fat thickness, mm										
At mixing	14.3	14.2	0.71	14.3	13.8	14.6	0.78	0.83	0.53	0.82
Before farrowing	15.6	16	0.79	16.3	15.4	15.7	0.91	0.59	0.54	0.86
Condition score										
At mixing	2.8	2.8	0.05	2.8	2.8	2.8	0.06	0.28	0.82	0.52
Before farrowing	2.9	2.9	0.04	2.9	2.9	2.9	0.05	0.76	0.40	0.09

[1] Limited represents that sows were limited to access feeding stalls only for feeding and Continuous represents that sows were allowed to access feeding stalls continuously during the initial 48 h after mixing.

[2] Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3] Percent of sows weaned for mating. Tested by Chi-square. Chi-square = 0.037 for pen treatment; Chi-square = 0.815 for social rank.

[4] Sows were mixed in pens at weaning.

[5] Sows were moved to farrowing rooms at 110 d of gestation.

[6] Sows were weaned at 5 wks after farrowing.

Table 2. Effects of stall access and social rank on aggression, skin lesions, and fear response of gestating sows in a group-housing system with individual feeding stalls

	Stall Access[1]			Social Rank[2]				P-value		
Item	Limited	Continuous	SEM	High	Middle	Low	SEM	Stall access	Social rank	Interaction
Number of sows	75	75		50	50	50				
Aggression at mixing[3], #/sow/6h										
Total fights	49.9	37.9	3.1	59.9[a]	34.8[c]	39.5[b]	3.8	<0.001	<0.001	<0.001
Knocks and bites	39.2	28.2	2.2	47.5[a]	26.3[c]	29.4[b]	2.8	<0.001	<0.001	<0.001
Threats	9.1	8.1	2.0	10.3[e]	7.1[f]	8.6[ef]	2.5	0.38	0.10	0.20
Pressing	0.6	0.5	0.22	0.9[a]	0.6[ab]	0.3[b]	0.2	0.61	0.04	0.17
Wins, %	27.4	23.2	2.1	70.8[a]	33.3[b]	6.8[c]	3.1	0.14	<0.001	0.01
Losses, %	42.5	47.3	2.8	19.3[a]	62.0[b]	75.5[b]	4.4	0.19	<0.001	0.66
Ties, %	0.31	0.28	0.19	0.11	0.56	0.22	0.22	0.90	0.09	0.84
Scores for skin lesion at 48 h after mixing										
Total	12.6	10.5	0.68	10.6	11.8	12.2	0.72	0.01	0.12	0.37
Head and shoulders	6.6	5.7	0.41	6.0	6.5	5.9	0.47	0.04	0.48	0.87
Other parts	6.1	4.8	0.52	4.9	5.5	5.9	0.55	0.02	0.36	0.52
Fear score at 5 wks after mixing[4]	3.2	2.8	0.42	3.7[a]	3.5[a]	2.1[b]	0.50	0.27	0.01	0.02

[1]Limited represents that sows were limited to access feeding stalls only for feeding and Continuous represents that sows were allowed to access feeding stalls continuously during the initial 48 h after mixing.
[2] Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.
[3]Sows were mixed in pens at weaning.
[4]Scale 0 to 6 with 0 representing most fearful and 6 representing least fearful.

Table 3. Time spent by sows of differing rank in feeding stalls during the initial 10 h after mixing in a group-housing system.

	Social Rank				
Item	High	Middle	Low	SEM	P-value
Time spent in stalls, % of observation time					
0 - 10 h	5.8[a]	9.7[b]	13.4[b]	2.83	0.001
0 - 4 h	6.9[a]	19.6[b]	27.2[b]	4.75	<0.001
4 - 8 h	5.8	4.0	6.4	2.69	0.40

[ab]Means without a common superscript differ ($P < 0.05$).

Table 4. Effects of stall access and social rank on reproductive performance of breeding sows

	Stall Access[1]		Social Rank[2]			P-value		
Item	Limited	Continuous	High	Low	SEM	Stall access	Social rank	Interaction
Number of focal sows	40	40	40	40				
Parity	2.7	2.3	3.7	1.7	0.27	0.29	<0.001	0.30
Litter size								
Total born	12.5	12.9	13.4	12.0	0.67	0.69	0.17	0.36
Live born	12.0	12.5	12.8	11.8	0.63	0.63	0.25	0.42
Still born	0.4	0.3	0.5	0.3	0.10	0.90	0.30	0.58
Dead before weaning[3]	3.3	3.4	4.0	2.8	0.51	0.89	0.03	0.22
Weaned	8.6	8.8	8.4	9.0	0.46	0.71	0.43	0.16
Piglet weight, kg								
At birth	1.5	1.5	1.5	1.6	0.04	0.80	0.37	0.78
At weaning	9.3	8.9	8.8	9.3	0.39	0.52	0.23	0.23

[1]Limited represents that sows were limited to access feeding stalls only for feeding and Continuous represents that sows were allowed to access feeding stalls continuously during the initial 48 h after mixing.

[2]Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3]Piglets were weaned at 5 wks after birth.

Table 5. Effects of stall access and maternal social rank on aggression of piglets at mixing during lactation

	Stall Access[1]		Social Rank[2]			P-value		
Item	Limited	Continuous	High	Low	SEM	Stall access	Social rank	Interaction
Number of focal piglets	80	80	80	80				
Aggression at mixing[3],								
Number of fights, fights/pig/2h	1.7	2.0	2.1	1.7	0.38	0.57	0.41	0.43
Wins, %	24.4	17.6	18.6	23.1	2.27	0.001	0.01	0.22
Losses, %	25.8	18.5	22.9	20.8	3.06	0.001	0.21	0.52
Ties, %	48.6	62.6	56.3	54.1	4.73	0.001	0.42	0.91

[1]Limited represents that sows were limited to access feeding stalls only for feeding and Continuous represents that sows were allowed to access feeding stalls continuously during the initial 48 h after mixing.

[2]Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3]Piglets were mixed at 10 d of age when farrowing pens were removed, and sows and piglets within a room commingled into a large group.

Table 6. Effects of group size and social rank on aggression and skin lesions in gestating sows in a group-housing system with floor feeding

	Group Size[1]		Social Rank[2]			P-value		
Item	Large	Small	High	Middle	Low	Group size	Social rank	Interaction
Number of sows	104	48	48	56	48			
Parity	3.3±0.18	2.0±0.21	2.9±0.27	2.5±0.34	2.4±0.25	<0.001	0.32	0.64
Aggression at mixing[3]								
Fights/sow/2h	12.7±1.25	12.2±1.76	20.7±3.17[a]	10.0±1.47[b]	9.3±1.42[b]	0.83	0.01	0.63
Wins, %	30.4±3.70	13.4±2.43	64.5±12.00[a]	15.7±1.58[b]	8.1±2.90[c]	0.01	<0.001	0.01
Losses, %	58.5±5.76	61.8±8.92	31.6±4.8[a]	77.4±11.4[ab]	88.7±13.6[b]	0.75	<0.001	0.3
Ties, %	3.4±0.69	1.0±0.86	3.2±0.89	2.2±0.87	1.2±0.89	0.01	0.16	0.93
Aggression at feeding[4]								
Fights/sow	3.2±0.28	2.7±0.34	3.9±0.46[a]	2.8±0.36[ab]	2.3±0.31[b]	0.27	0.01	0.32
Scores for skin lesion								
24 h after mixing	14.6±1.08	11.8±0.96	13.0±1.07	14.0±1.12	12.4±1.02	<0.001	0.11	0.05
Before farrowing[5]	8.3±0.63	5.6±0.59	5.3±0.60[a]	7.2±0.74[ab]	8.3±0.87[b]	0.01	0.01	0.49

[1]The large group housed 26 sows per pen, and the small group housed 6 sows per pen, both pens provided equal floor space allowance (16.5 sq ft per sow).

[2]Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3]Sows were mixed after pregnancy confirmation at 5 wks after mating.

[4]The first two meals after mixing in group pens.

[5]Sows were moved for farrowing at 109 d of gestation.

Table 7. Effects of group size and social rank on body weights and conditions of gestating sows in a group-housing system with floor feeding

	Group Size[1]		Social Rank[2]			*P*-value		
Item	Large	Small	High	Middle	Low	Group size	Social rank	Interaction
Number of sows	104	48	48	56	48			
Parity	3.3±0.18	2.0±0.21	2.9±0.27	2.5±0.34	2.4±0.25	<0.001	0.32	0.64
Weight, kg								
At mixing (wt1)[3]	227±3.6	207±4.5	218±4.7	214±4.6	218±4.7	<0.001	0.65	0.37
Before farrowing (wt2)[4]	262±5.0	247±5.7	268±5.9[a]	245±5.7[b]	251±6.0[b]	0.01	0.01	0.35
At weaning (wt3)[5]	235±5.7	218±6.3	232±6.5[e]	219±6.3[f]	226±6.6[ef]	0.01	0.08	0.08
Change in weight, kg								
Gestation (wt2-wt1)	36±5.1	41±5.4	50±5.6[a]	33±5.5[b]	33±5.6[b]	0.18	<0.001	0.16
Lactation (wt3-wt2)	-28±2.0	-30±2.6	-37±2.9	-25±2.7	-24±2.9	0.43	0.01	0.01
Condition score								
At mixing	2.9±0.04	2.7±0.05	2.8±0.06	2.8±0.06	2.8±0.06	0.02	0.89	0.79
Before farrowing	2.9±0.03	2.9±0.05	3.0±0.05[e]	2.9±0.05[f]	2.9±0.05[f]	0.60	0.08	0.96

[1]The large group housed 26 sows per pen, and the small group housed 6 sows per pen, both pens provided equal floor space allowance (16.5 sq ft per sow).

[2]Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3]Sows were mixed in group pens after pregnancy confirmation at 5 wks after mating.

[4]Sows were moved to farrowing rooms at 111 d of gestation.

[5]Weaning occurred at 3 wks after farrowing.

Table 8. Effects of group size and social rank on reproductive performance of sows that were group-housed during gestation

	Group Size[1]		Social Rank[2]			*P*-value		
Item	Large	Small	High	Middle	Low	Group size	Social rank	Interaction
Number of sows recorded pregnant	103	47	47	56	47			
Number of sows farrowed	90	46	42	53	41			
Farrowing rate, %[3]	87.4	97.9	89.4	94.6	87.2	0.04	0.41	-
Litter size								
Total born	13.9±0.40	13.6±0.54	13.5±0.59	13.3±0.62	14.5±0.55	0.58	0.28	0.39
Live born	12.8±0.38	12.5±0.52	12.4±0.57	12.4±0.54	13.2±0.59	0.55	0.49	0.33
Still born	0.7±0.13	0.7±0.10	0.8±0.14	0.8±0.11	0.6±0.15	0.88	0.28	0.78
Mummies	0.3±0.06	0.3±0.09	0.2±0.08	0.3±0.09	0.5±0.11	0.86	0.29	0.78
Weaned[4]	11.0±0.19	11.0±0.23	10.9±0.24	11.2±0.23	10.9±0.25	0.68	0.43	0.28
Piglet weight at weaning, kg								
Litter weight	71.5±1.35	71.5±1.63	71.3±1.72	73.5±1.66	69.8±1.77	0.99	0.21	0.20
Piglet weight	6.5±0.08	6.5±0.09	6.6±0.09	6.6±0.10	6.4±0.10	0.43	0.15	0.66
Wean-to-mate interval, d	6.1±0.64	4.7±0.55	5.1±0.61	5.1±0.60	6.0±0.69	0.01	0.14	0.01

[1]The large group housed 26 sows per pen, and the small group housed 6 sows per pen, both pens provided equal floor space allowance (16.5 sq ft per sow).

[2]Sows were categorized as high, middle or low rank based on outcomes of aggression at mixing.

[3] Farrowing rate = the number of sows diagnosed pregnant/the number of sows farrowed x 100%; for Group Size treatment, Chi-square = 4.200 (*P* = 0.04); for Social Rank, Chi-square = 1.795 (*P* = 0.41).

[4]Piglets were weaned at 3 wks after birth.

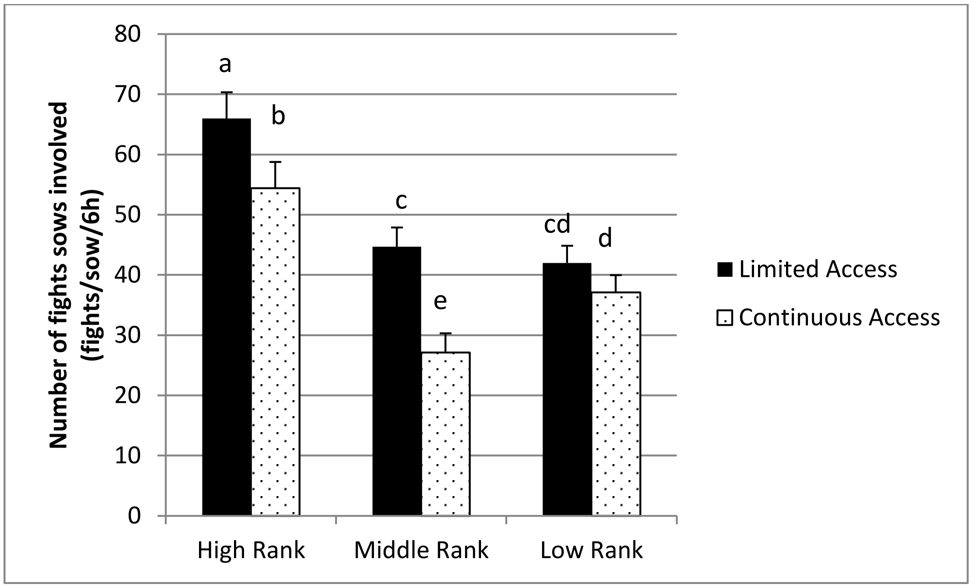

Fig. 1. Interactive effect of stall access and social rank on aggression among gestating sows during the initial 6 h after mixing in a group housing system with individual feeding stalls. [abcde]Means without a common superscript differ ($P < 0.05$).

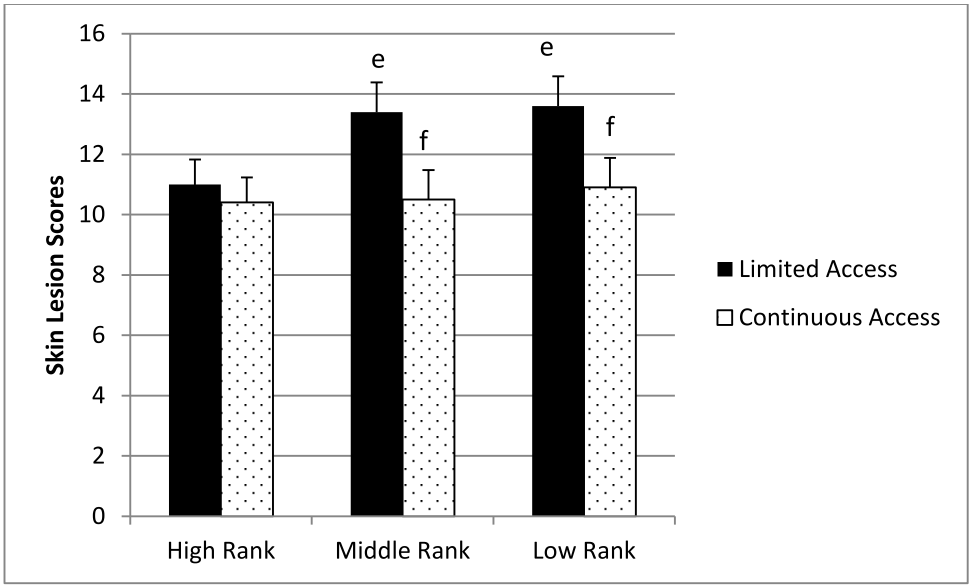

Fig. 2. Interactive effect of stall access and social rank on skin lesion scores of gestating sows at 48 h after mixing in a group-housing system with individual feeding stalls.
[ef]Means without a common superscript tended to differ ($P < 0.10$).

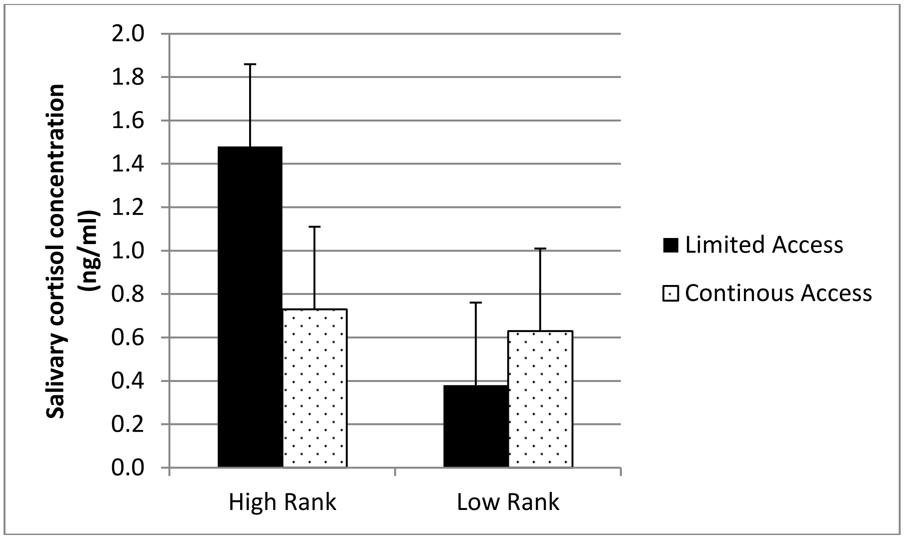

Fig. 3. Interactive effect of stall access and social rank on salivary cortisol concentrations of gestating sows after 5 wks entering a group-housing system with individual feeding stalls.

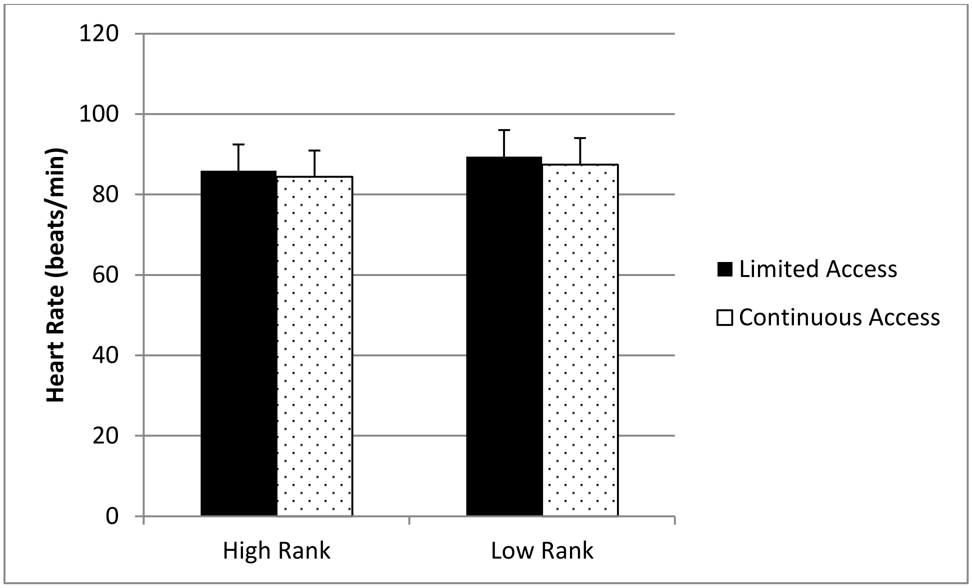

Fig. 4. Interactive effect of stall access and social rank on heart rate of gestating sows after 5 wks entering a group-housing system with individual feeding stalls.

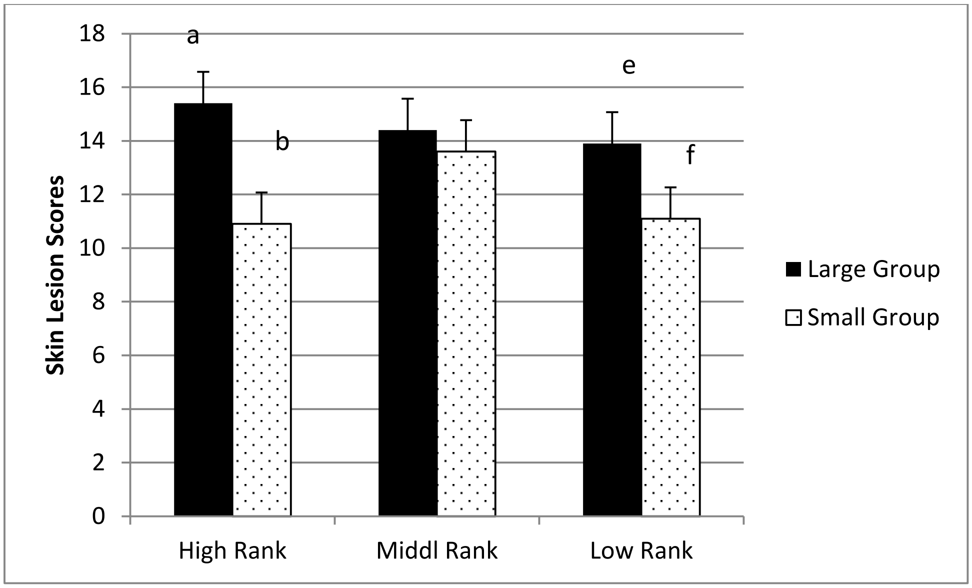

Fig. 5. Interaction of group size and social rank on skin lesion scores of gestating sows at 24 h after mixing in a group-housing system with floor feeding.

[ab]Means without a common superscript differ ($P < 0.01$).

[ef]Means without a common superscript tended to differ ($P = 0.10$).

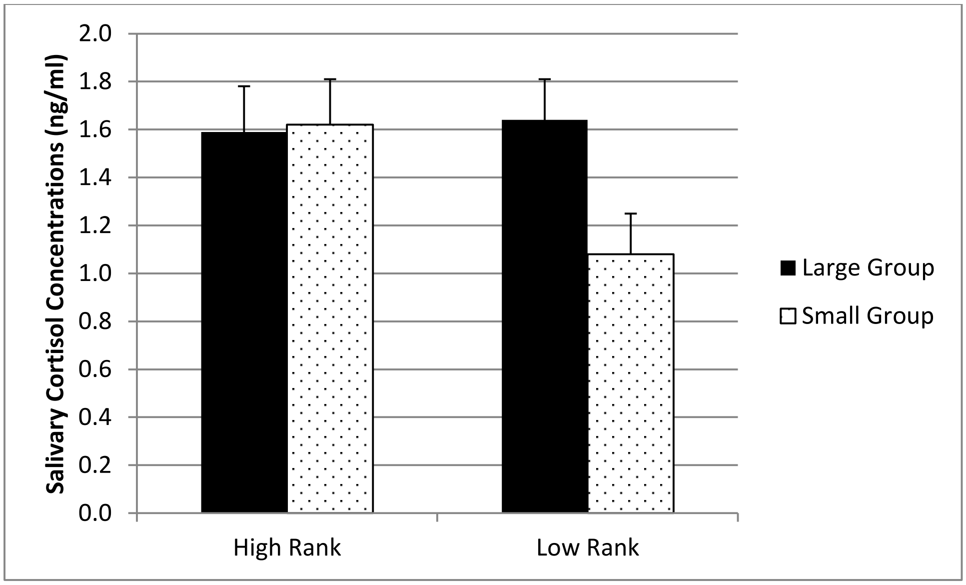

Fig. 6. Interactive effect of group size and social rank on salivary cortisol concentrations of gestating sows in a group housing system with floor feeding. [ef]Means without a common superscript within a social rank tended to differ (*P* = 0.10)