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Effects of social rank on welfare and performance of gestating sows housed in two group sizes

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Summary

Objectives: To compare welfare and performance among low-, middle-, and high-ranking sows in two group sizes of gestation pens.

Materials and methods: Pregnant sows (n = 152) were allocated to four pens of 26 sows (large-group pen) and eight pens of six sows (small-group pen) with floor feeding. Social rank was based on outcomes of aggression during mixing. Skin lesions were assessed for all sows and salivary cortisol concentrations were measured for 32 focal sows. Performance during gestation and lactation was recorded for all sows.

Results: Across the two group sizes, low-ranking sows fought less frequently, but had higher salivary cortisol concentrations and sustained similar skin lesions at mixing compared to high-ranking sows. Low-ranking sows had more skin lesions 5 weeks after mixing, gained less weight during gestation, and had lower body weight before farrowing than high-ranking sows. Social rank did not affect litter size farrowed, litter size weaned, or litter weight at weaning.

Implications: Under the conditions of this study, regardless of the group size adopted, low-ranking sows have poorer welfare than high-ranking sows in a group housing system with floor feeding, demonstrated by their having more skin lesions, higher cortisol levels, and less weight gain during the gestation period than high-ranking sows.

Keywords: swine, gestation housing, social rank, sow, welfare

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Resumen - Efectos del rango social en el bienestar y desempeño de las hembras gestantes alojadas en dos tamaños de grupo

Objetivos: Comparar el bienestar y desempeño entre hembras de rango bajo-, medio-, y alto en grupos de dos tamaños de corrales de gestación.

Materiales y métodos: Se alojaron (n = 152) hembras gestantes en cuatro corrales de 26 hembras (corral de grupo grande) y ocho corrales de seis hembras (corral de grupo pequeño) con alimentación al piso. El rango social se basó en resultados de agresión durante la reagrupación. Se valoraron las lesiones de piel de todas las hembras y se midieron las concentraciones de cortisol salival de 32 hembras principales. Se registraron el desempeño durante la gestación, y la lactancia de todas las hembras.

Resultados: En los dos tamaños de grupo, las hembras de bajo rango pelaron con menos frecuencia, pero tuvieron concentraciones de cortisol salivales más altas, y comparadas con las hembras de alto tanto, tuvieron lesiones de piel similares. Las hembras de bajo rango tuvieron más lesiones de piel 5 semanas después de la reagrupación, ganaron menos peso, y tuvieron menos peso corporal antes de parir que las hembras de alto rango. El rango social, no afectó el tamaño de la camada parida, el tamaño de la camada destetada, o el peso de la camada al destete.

Implicaciones: Bajo las condiciones de este estudio, en todos los tamaños de grupos, las hembras de bajo rango tuvieron un menor bienestar que las hembras de alto rango en el sistema de alojamiento en grupos con alimentación al piso; demostrado por el hecho de tener más lesiones de piel, niveles más altos de cortisol, y menor ganancia de peso durante el periodo de gestación que las hembras de alto rango.

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Résumé - Effets du rang social sur le bien-être et les performances de truies en gestation hébergées dans deux groupes de taille différente

Objectifs: Comparer le bien-être et les performances de truies de rang social bas, moyen et haut hébergées en deux groupes de taille différente dans des enclos de gestation.

Matériels et méthodes: Des truies gestantes (n = 152) ont été réparties dans quatre parcs de 26 truies (enclos grand groupe) et huit parcs de six truies (enclos petit groupe) et nourries au sol. Le rang social fut déterminé selon les résultats de l'agressivité au moment du mélange des animaux. Les lésions cutanées ont été évaluées pour toutes les truies et les concentrations de cortisol salivaire ont été mesurées pour 32 truies. Les performances durant la gestation et la lactation ont été enregistrées pour toutes les truies.

Résultats: Entre les groupes des deux tailles, les truies de bas rang social se battaient moins souvent mais avaient des concentrations de cortisol salivaire plus élevées et au moment du mélange ont subi des lésions cutanées similaires à celles de rang social élevé. Les truies de bas rang social avaient plus de lésions cutanées 5 semaines après le mélange, ont pris moins de poids durant la gestation, et avaient un poids corporel plus faible avant la mise-bas que les truies de rang social élevé. Le rang social n'a pas affecté

la taille de la portée mise-bas, le taille de la portée sevrée, ou le poids de la portée au moment du sevrage.

Implications: Dans les conditions expérimentales de la présente étude, indépendamment de la taille du groupe observé, le bien-être des truies de bas rang social était moindre que celui des truies à rang social élevé dans un système d'hébergement en groupe avec distribution de nourriture au sol, tel que démontré par le fait qu'elles avaient plus de lésions cutanées, des concentrations de cortisol plus élevées, et un gain de poids moindre durant la gestation que les truies de rang social élevé.

In response to concerns for animal welfare, the European Union countries and several states in the United States have banned gestation stalls through legislation. Meanwhile, some pork producers have voluntarily committed to replace gestation stalls with group housing systems to meet consumers' demands for improved animal welfare in modern pork production systems. While sow welfare may differ depending on the housing system provided,[1,2] the welfare of individual sows within a given group-housing system can vary greatly.[3] One of the important contributing factors to variation in sow welfare is social rank of the sow within a group of sows. Previous researchers[4,5] have suggested that low-ranking sows usually suffer from poor welfare, compared to sows with higher social rank. O'Connell et al[4] demonstrated that low-ranking sows had more injuries caused by initial fighting at mixing than high-ranking sows. After losing most fights, low-ranking sows may become fearful of further conflicts when attempting to obtain feed, which can lead to inadequate feed intake,[5] less weight gain and poorer body condition,[6] smaller litter size at farrowing[7] and lighter pigs at weaning[6] compared to higher-ranking sows. These problems may become more prominent when floor-feeding systems are used for group-housed sows. Although floor feeding is not an ideal system for group-housed sows due to difficulties of controlling individual feed intake,[1,2] many producers, including some large-scale producers in the United States, still choose to adopt this system because of its low capital investment, no requirement for staff to use computers, and efficient use of floor space.[8,9] The welfare status of individual sows in pens with a floor feeding system has not been evaluated systematically.

The welfare of individual sows, especially of low-ranking sows, may differ when housed in different group sizes.[10,11] When housed 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.[12] In contrast, when housed in large groups with the associated larger pens, low-ranking sows have more space to escape from fighting, but also are exposed to a larger number of more dominant sows.[13] To the knowledge of the authors, the welfare and performance of low-ranking sows in different group sizes have not been assessed. The objective of the current study was to evaluate the welfare and performance of gestating sows of different social ranks that were housed in groups of two sizes using a floor feeding system.

Materials and methods

Animals, housing, and management

The Institutional Animal Care and Use Committee of the University of Minnesota reviewed and approved the experimental protocol for this study.

The animal trial was conducted on a commercial 5000-sow breed-to-wean farm between 10 November 2010 and 20 July 2011. Four pens, each housing 26 sows (large-group pen), and eight pens, each housing six sows (small-group pen), were retrofitted from gestation stalls and used for this study.[14] Both large-group pens (5.5 m × 7.3 m) and small-group pens (5.5 m × 1.7 m) had partially slatted floors. The solid areas in each large pen were divided by metal gates (1.8 m) into six smaller areas so that sows could be fed and rest in smaller sections and in smaller subgroups. Each large-group pen was equipped with four bowl drinkers, and each small-group pen had one bowl drinker. Floor space allowance was 1.5 m^2 per sow in both large- and small-group pens. All sows were provided 2.5 kg of a corn-soybean meal-based gestation diet formulated to meet or exceed National Research Council nutritional requirements for gestating sows.[15] The daily ration was delivered in two portions, with two thirds of the ration delivered at 6:00 AM and one third delivered at 12:00 PM. Feed was dropped on the solid portion of the floor from existing feeder lines so that a small pile of feed was dropped for each sow. 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. During the study period, average daily temperature in the gestation barn ranged between 10°C and 22°C. Light period was 9 hours, starting from 6:00 AM, with emergency lights on during the dark period. Room temperature, feeders, drinkers, and animal health were checked daily in the morning and afternoon. When any sow was removed from the study, the reason for removal was recorded.

Sows (parity 1 to 6, Camborough-PIC North America, Hendersonville, Tennessee) had been housed in individual stalls during their previous gestation and lactation. At weaning, sows were moved to and bred in gestation stalls. At approximately 35 days after breeding, sows were tested for pregnancy by ultrasound, and pregnant sows were allocated to gestation pens. Sows from each breeding cohort were assigned to one large-group pen and two small-group pens. Sows remained in their pens until approximately day 109 of gestation, when they were moved to farrowing rooms. Sows farrowed in crates and cross-fostering was conducted within 48 hours after farrowing. Litters were weaned at approximately 21 days after farrowing and sows were bred for the next breeding cycle within a week. This procedure was repeated for four contemporary breeding cohorts at 4- to 6-week intervals. In total, 152 sows were used, with 104 sows assigned to four large-group pens and 48 sows to eight small-group pens.

Sow allocation to gestation pens

At allocation, sows in each breeding cohort were sorted by parity and by body size. Parity was categorized at breeding as parity 1, parity 2, and parity 3 or greater (parity 3+). Body size was classified as large or small by visual appraisal as previously reported.[14] For each breeding cohort, the ratio of large to small sows was calculated. Then, a subset of 26 sows with both the ratio of large to small body size and parity composition similar to those of the breeding cohort were selected and allocated to a large-group pen: the large-group pen housed both large and small sows. In contrast to the large-group pen, the two small-group pens each consisted of a pen with sows of small body size and a pen with sows of large body size. The average ratio of large to small sows was 3.5:1 in the study. The average ratio of parity 1 to parity 2 to parity 3+ was approximately1:3:9 for large sows, and approximately 2:3:1 for small sows.

Data collection

Production performance. The data collection period started when sows were allocated to pens after pregnancy confirmation and continued until they were bred for the next reproductive cycle after weaning their litters. All sows were weighed individually at allocation to pens, at entry to farrowing rooms, and at weaning. Body condition was assessed by visual appraisal using a 1 to 5 scale system.[16] Each sow was scored for body condition at allocation to gestation pens and before being moved to farrowing stalls. All body condition scores were assessed by two trained researchers. Each scored a small-group pen and half of a large-group pen for each breeding cohort. 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 (total born, number born alive, number stillborn, and number mummified for each litter), and litter size and litter weight at weaning. Farrowing rate was calculated on the basis of the number of sows farrowed as a percentage of sows assigned to the study after pregnancy confirmation. Sows that farrowed and weaned a litter and that were bred for the next breeding cycle within a week were considered to have completed the study. Completion rate was calculated as the number of sows that completed the study as a percentage of sows assigned to the study. Wean-to-estrus intervals were recorded for sows that expressed estrus within a week after weaning.

Social rank and aggression at mixing. All sows were mixed in pens between 9:00 AM and 10:00 AM. Aggressive interactions among sows at mixing and during the first two meals after mixing were recorded by continuous live observations. Aggressive interactions were classified as pushing and biting, according to the methodology used by previous researchers.[4,17] Pushing was defined as sows standing side-by-side and pushing hard with their shoulders against each other, generally performed with frequent bites. Biting was defined as a sow delivering rapid bites or knocks with the snout against the head or body of the receiver. Before observations started, the back of each sow was painted with a unique color and pattern for individual identification. To record aggressive interactions at mixing, the observations started immediately after all sows were moved into a pen and continued for 2 hours. Observations during feeding started from the time when feeder lines were turned on to drop feed until sows in the pen had consumed all feed. The first feeding after mixing started at noon on the mixing day, and the second feeding started at 6:00 AM the next morning. Two researchers were trained to conduct the live observations. Each researcher was assigned to record either two small-group pens or a large-group pen during each recording period. The number and outcomes (wins, losses, and stand-offs) of aggressive interactions, and individual sows that were involved, were registered using a 26 × 26 winner-loser matrix[18] for each large group and a 6 × 6 winner-loser matrix for each small group. On the basis of the number of wins and losses, a rank index (RI) was calculated for each sow using the equation

$$RI = [(S \times P_s) - (N \times P_n)] \div [(S + N) \times (n - 1)]$$

where S = the number of wins, P_s = the number of opponents that the sow had defeated, N = the number of losses, P_n = the number of opponents by which the sow was defeated, and n = the total number of sows in the pen.[19] On the basis of the rank indices (in the range of 1 to -1), each sow in a pen was ranked in order, with rank 1 as the most dominant. For further data analysis, sows in small-group pens with rank 1 to 2 were arbitrarily classified as high-ranking sows, rank 3 to 4 as middle-ranking sows, and rank 5 to 6 as low-ranking sows. Likewise, sows in large-group pens with rank 1 to 8 were classified as high-ranking sows, rank 9 to 18 as middle-ranking sows, and rank 19 to 26 as low-ranking sows. As a result, in each small-group pen, a group of two sows was categorized as high-, middle-, or low-ranking sows, respectively. In each large-group pen, a group of eight sows was categorized as high- or low-ranking, respectively, and a group of 10 sows as middle-ranking.

Skin lesions. To evaluate injuries caused by aggressive interactions, fresh skin lesions were assessed for each sow at 24 hours and 5 weeks after mixing in gestation pens. Skin lesions were assessed using the methodology of Hodgkiss et al,[20] 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 was 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); and 3 = severe injury (> 10 superficial wounds, and [or] > 3 deep wounds).

Salivary cortisol concentrations. Salivary samples were collected between 9:00 AM and 10:00 AM from 16 sows in large-group pens with two high-ranking and two low-ranking sows from each pen, and 16 sows from small-group pens with one high-ranking and one low-ranking sow from each pen. The samples were collected at 24 hours and 5 weeks after mixing using cotton swabs provided with the Salivette tubes (Sarstedt Ltd, Numbrecht, Germany). The cotton swab was secured to 150 cm of dental floss and placed into the mouth of the sow with minimal disturbance to the sow. Sows were allowed to chew on the swab until it was saturated with saliva. To avoid cortisol level being elevated by handling stress, each saliva sample was collected within 3 minutes of approaching the sow. Saliva was removed by centrifugation at 1500*g* for 5 minutes and frozen at -20°C for subsequent analysis. Cortisol concentration was determined by radioimmunoassay using Coat-A-Count Cortisol kits (Siemens Medical Solutions, Malvern, Pennsylvania), according to the methods of Anil et al.[21] All saliva samples were analyzed within the same assay. The intra-assay covariate (coefficient of variance) was less than 10%, and the sensitivity of the assay was 0.04 ng per mL.

Data analyses. Data were analyzed using the SAS package (version 9.4; SAS Institute Inc, Cary, North Carolina.). The Frequency procedure with Chi-square test was used to analyze the number of sows that farrowed and completed the study. The GLIMMIX procedure was used to analyze the remaining 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. Within small-group pens, the effect of sorting by body size was examined initially, and no significant difference for any variable (all $P > .10$) was detected. The effect of sow size was therefore excluded from final statistical models, and the data from small and large sows were combined for small-group pens. To test effects of social rank, the same model was used, but separate analyses were conducted for each group size. The model included social rank as the fixed effect and replicate (breeding cohort) as the random effect. To increase test power, effects of social rank were further examined across

both group sizes using data from the two group-pen sizes. The models included social rank, pen size, and their interactions as fixed effects, with replicate (breeding cohort) serving as the random effect. Since no significant difference (all $P > .34$) was detected in parity among social ranks, parity was not included in any of the final statistical models. Rank group within each pen was the experimental unit for all data analysis, except for cortisol concentration and farrowing performance, where individual sow was the experimental unit. Differences among means were tested by PDIFF with the Tukey adjustment for multiple comparisons. Significant differences among means were identified at $P < .05$ and trends at $P < .10$.

Results

In large-group pens, low-ranking sows tended to have fewer aggressive interactions ($P = .054$; Table 1) than high-ranking sows. Social rank did not affect other variables measured, except that low-ranking sows tended to lose less weight ($P = .051$) during lactation than high-ranking sows.

In small-group pens, social rank affected the number of aggressive interactions during mixing, with low- and middle-ranking sows having fewer aggressive interactions ($P = .04$; Table 2) than high-ranking sows. In addition, low- and middle-ranking sows were lighter before farrowing ($P = .002$) and gained less weight during gestation ($P = .04$), and low-ranking sows tended to lose less weight during lactation ($P = .07$) than high-ranking sows. Social rank did not affect other variables measured in small-group pens.

Across two group sizes, low-ranking sows had fewer aggressive interactions at mixing ($P = .003$; Table 3) and during the initial feedings ($P = .048$) than high-ranking sows. Similar to low-ranking sows, middle-ranking sows experienced fewer aggressive interactions than high-ranking sows. Social rank did not affect skin lesion scores at 24 hours after mixing, but low-ranking sows had more skin lesions than high-ranking sows ($P = .02$) 5 weeks after entering gestation pens, with middle-ranking sows being intermediate.

There were no differences in parity, body weight, or condition score among sows in different social ranks when they entered the gestation pens. However, low- and middle-ranking sows gained less weight during gestation ($P = .01$) and lost less weight during lactation ($P = .01$) than high-ranking sows. As a result, low- and middle-ranking sows were lighter than high-ranking sows before farrowing ($P = .003$), but this difference in body weight between low- and high-ranking sows was not observed when sows weaned their subsequent litters. There was an interaction between group size and social rank for weight change during the lactation period, with middle-ranking sows losing less weight than high-ranking sows when gestated in small-group pens, but not when gestated in large-group pens. There was no interaction between group size and social rank for other variables.

Table 1: Effects of social rank on aggression, skin lesions, and performance of gestating sows housed in four pens of 26 sows with floor feeding*

	Social rank†			
Parameter	**High**	**Middle**	**Low**	***P***
Number of sows per pen	8	10	8	NA
Parity	3.5 ± 0.33	3.0 ± 0.27	3.3 ± 0.32	.49
Aggressive interactions at mixing (no./sow)‡	18.9 ± 3.35^{e}	11.2 ± 1.77^{ef}	9.6 ± 1.70^{f}	.054
Aggressive interactions at feeding (no./sow/meal)§	1.95 ± 0.30	1.76 ± 0.26	1.15 ± 0.22	.14
Skin lesions (average score/sow)				
24 hours after mixing	15.5 ± 1.19	14.5 ± 1.10	13.9 ± 1.09	.63
5 weeks after mixing	7.1 ± 0.85	8.1 ± 0.88	9.8 ± 1.15	.19
Weight (kg)				
Before mixing	228.1 ± 4.9	220.3 ± 4.4	231.9 ± 4.9	.19
Before farrowing	271.4 ± 6.2	252.6 ± 5.4	262.5 ± 6.2	.12
At weaning	240.3 ± 7.4	222.6 ± 6.9	242.5 ± 7.8	.16
Change in weight (kg)				
Between mixing and farrowing	44.9 ± 6.0	35.2 ± 5.6	29.3 ± 6.0	.23
Between farrowing and weaning	-32.3 ± 3.3^{e}	-30.7 ± 2.8^{e}	-19.7 ± 3.5^{f}	.051
Condition score				
Before mixing	2.89 ± 0.06	2.89 ± 0.05	2.81 ± 0.06	.55
Before farrowing	3.02 ± 0.06	2.90 ± 0.06	2.87 ± 0.07	.27

* Each pen provided floor space allowance of 1.5 m^2/sow.
† Sows were categorized as high, middle, or low rank, based on outcomes of aggression at mixing.
‡ Total number of aggressive interactions during the initial 2 hours after mixing. Sows were mixed in gestation pens after pregnancy confirmation 5 weeks after breeding.
§ Aggressive interactions per meal during the first two meals after mixing in group pens. Meals were fed 2 and 18 hours after mixing.
^{ef} Means within a row with no common superscript tend to differ (Tukey test adjusted for multiple comparisons; $P < .10$).
NA = not applicable.

Table 2: Effects of social rank on aggression, skin lesions, and performance of gestating sows housed in eight pens of six sows with floor feeding*

	Social rank†				
Parameter	**High**	**Middle**	**Low**	**SEM**	***P***
No. of sows/pen	2	2	2	NA	NA
Parity	2.3	2.1	1.8	0.3	.56
Aggressive interactions at mixing (no./sow)‡	22.7 ± 5.7[a]	8.9 ± 2.2[b]	9.0 ± 2.3[b]	NA	.04
Aggressive interactions at feeding (no./sow/meal)§	1.9 ± 0.3	1.4 ± 0.3	1.2 ± 0.3	NA	.17
Skin lesions (average score/sow)					
24 hours after mixing	11.0	13.5	11.1	1.3	.41
5 weeks after mixing	4.0	6.4	6.9	1.1	.14
Weight (kg)					
Before mixing	208.6	207.7	204.3	4.75	.80
Before farrowing	264.9[a]	238.4[b]	238.3[b]	5.79	.002
At weaning	225.2	216.4	211.0	7.54	.44
Change in weight (kg)					
Between mixing and farrowing	56.3[a]	30.7[b]	36.9[b]	6.16	.04
Between farrowing and weaning	-41.7[e]	-20.2[f]	-28.8[ef]	5.82	.07
Condition score					
Before mixing	2.72	2.69	2.72	0.12	.97
Before farrowing	3.06	2.91	2.91	0.07	.25

* Each pen provided a floor space allowance of 1.5 m^2/sow.
† Sows were categorized as high, middle, or low rank, based on outcomes of aggression at mixing sows in each rank per pen.
‡ Total number of aggressive interactions during the initial 2 hours after mixing. Sows were mixed in gestation pens after pregnancy confirmation at 5 weeks after breeding.
§ Aggressive interactions per meal during the first two meals after mixing in group pens. Meals were fed at 2 and 18 hours after mixing.
[ab] Means within a row with no common superscript differ (Tukey test adjusted for multiple comparisons; $P < .05$).
[ef] Means within a row with no common superscript tend to differ (Tukey test adjusted for multiple comparisons; $P < .10$).
NA = not applicable; SEM = standard error of the mean.

Compared with high-ranking sows, low-ranking sows had higher salivary cortisol concentrations at 24 hours after mixing ($P = .046$; Table 4), but this difference was not observed 5 weeks later.

Among the 152 sows used for the study, 136 farrowed, with an overall farrowing rate of 89.5% (Table 5). Social rank did not affect farrowing rates or completion rates in either large or small group pens.

Twenty-five sows that did not complete the study were culled, resulting in an overall culling rate of 16% (Table 6). Low- and middle-ranking sows were most likely to be culled for injuries from fighting, while high-ranking sows were most likely to be culled for poor reproduction. Social rank of sows did not affect farrowing performance (Table 7).

Discussion

This study demonstrates that the degree of welfare for individual sows is associated with their social rank in a group. In general, low-ranking sows had poorer welfare than high-ranking sows in the group housing systems studied, as indicated by higher salivary cortisol concentrations at mixing, more skin lesions at 5 weeks after mixing, less weight gain during gestation, and low body weight before farrowing. The degree of welfare of middle-ranking sows was either similar to that of low-ranking sows or intermediate between low- and high-ranking sows.

Skin lesions are indicative of welfare status of sows in a group-housing system. Turner et al[22] noted that skin lesions were correlated with the number of aggressive interactions that sows were involved in either during or after the period of mixing. However, in the current study, we observed that low-ranking sows were less involved in fighting, but sustained the same number of skin lesions as high-ranking sows at 24 hours after mixing. This suggests that the relationship between skin lesions and the number of aggressive interactions may depend on social rank of the sows. Consistent with our results, Mendl et al[23] reported that low-ranking sows fought less frequently than high-ranking sows, but injuries were similar to those of high-ranking sows. Likewise, Hemsworth et al[24] and Borberg and Hoy[25] reported that high-ranking sows initiated more fights and low-ranking sows received more fights in group pens, suggesting that sows that received fights were more likely to be injured. Indeed, in the current study, low-ranking sows had more fresh skin lesions 5 weeks after entering the gestation pens than high-ranking sows, which suggests that low-ranking sows received attacks from high-ranking sows after the establishment of dominance hierarchy.[26] When using a competitive

Table 3: Effects of social rank on aggression, skin lesions, and performance of gestating sows in 12 pens of two group sizes*

	Social rank†			
Parameter	**High**	**Middle**	**Low**	***P***
No. of sows/pen	2 or 8‡	2 or 10	2 or 8	NA
Parity	2.9 ± 0.3	2.5 ± 0.2	2.4 ± 0.3	.34
Aggressive interactions at mixing (no./sow)§	20.7 ± 3.2[a]	10.0 ± 1.5[b]	9.3 ± 1.4[b]	.003
Aggressive interactions at feeding (no./sow/meal)¶	1.9 ± 0.2[a]	1.4 ± 0.2[ab]	1.2 ± 0.2[b]	.048
Skin lesions (average score/sow)				
24 hours after mixing	13.0 ± 0.9	14.0 ± 0.9	12.4 ± 0.9	.47
5 weeks after mixing	5.3 ± 0.6[b]	7.2 ± ± 0.7[ab]	8.3 ± 0.8[a]	.02
Weight (kg)				
Before mixing	218 ± 3.9	214 ± 3.7	218 ± 3.9	.66
Before farrowing	268 ± 4.5[a]	245 ± 4.2[b]	251 ± 4.5[b]	.003
At weaning	233 ± 5.4	220 ± 5.6	227 ± 5.6	.23
Change in weight (kg)				
Between mixing and farrowing	50 ± 4.4[a]	31 ± 4.2[b]	33 ± 4.4[b]	.01
Between farrowing and weaning	-37 ± 3.1[a]	-25 ± 2.9[b]	-24 ± 3.2[b]	.01
Condition score				
Before mixing	2.8 ± 0.06	2.8 ± 0.06	2.8 ±0.06	.89
Before farrowing	3.0 ± 0.05	2.9 ± 0.05	2.9 ± 0.05	.10

* Both pen sizes (four pens of 26 sows/pen and eight pens of six sows/pen) provided equal floor space allowance (1.5 m^2/sow).
† Sows were categorized as high, middle, or low rank, based on outcomes of aggression at mixing.
‡ Two sows per small pen, and eight or 10 sows per large pen.
§ Total number of aggressive interactions during the initial 2 hours after mixing. Sows were mixed in gestation pens after pregnancy confirmation at 5 weeks after breeding.
¶ Aggressive interactions per meal during the first two meals after mixing in group pens. Meals were fed at 2 and 18 hours after mixing.
[ab] Means within a row with no common superscript differ (Tukey test adjusted for multiple comparisons; $P < .05$).
NA = not applicable.

Table 4: Effects of social rank on salivary cortisol concentrations of gestating sows housed in pens of 26 sows or six sows with floor feeding

	Social rank*			
Parameter	**High**	**Low**	**SEM**	***P***
No. of sows†	16	16	NA	NA
Parity	2.8	2.6	0.24	.63
Cortisol (ng/mL)				
24 hours after mixing	14.3[b]	20.1[a]	4.7	.046
5 weeks after mixing	14.0	12.5	1.5	.40

* Sows were categorized as high- or low-ranking, based on outcomes of aggression at mixing.
† Saliva samples were collected from two low-ranking and two high-ranking sows in each pen (n = 4) of 26 sows; and one low-ranking and one high-ranking sow in each pen (n = 8) of six sows. All sows were provided equal floor space allowance (1.5 m^2/sow).
[ab] Means within a row with no common superscript differ (Tukey test adjusted for multiple comparisons; $P < .05$).
NA = not applicable.

feeding system, as in the current study, sows may fight for feed each day during meals. More likely, low-ranking sows were attacked by high-ranking sows when competing for feed. Tonepohl et al[27] reported that even in a group-housing system with electronic sow feeders, low-ranking sows had more skin lesions than high-ranking sows 10 weeks after entering gestation pens.

Fighting is a stressful event for sows that increases cortisol levels.[28] Individual sows may be affected by fights differently, with losers of fights being more affected than winners. In the current study, low-ranking sows had higher salivary cortisol concentrations 24 hours after mixing than high-ranking sows, suggesting that low-ranking sows experienced more stress than high-ranking sows, although they were less involved in fighting during the initial mixing period.

Low-ranking sows were also less involved in fighting during the first two meals after

Table 5: Effects of social rank on the number of sows that gestated in either large or small pens and that farrowed and completed the study

	Large pen*					Small pen*				
Parameter	**HR†**	**MR†**	**LR†**	**Chi-square**	***P***	**HR†**	**MR†**	**LR†**	**Chi-square**	***P***
No. of sows assigned‡	32	40	32	NA	NA	16	16	16	NA	NA
No. of sows farrowed	26	37	26	NA	NA	15	16	16	NA	NA
Farrowing rate (%)§	81	93	81	2.52	0.28	94	100	100	2.04	0.36
No. of sows completed study¶	25	35	23	NA	NA	15	14	15	NA	NA
Retention rate (%)§	78	88	72	2.77	0.25	94	88	94	0.55	0.76

* The large pen housed 26 sows and the small pen housed six sows; both pens provided equal floor space allowance (1.5 m^2/sow).
† Sows were categorized as high (HR), middle (MR), or low ranking (LR) on the basis of outcomes of aggression at mixing.
‡ After confirming pregnancy at 5 weeks after breeding.
§ Percentage of sows assigned to the study.
¶ Farrowed and weaned a litter and started the next breeding cycle.
NA = not applicable.

mixing, which suggests that low-ranking sows may be less competitive at feeding than higher ranking sows. This might contribute to less weight gain for low-ranking sows during gestation compared with high-ranking sows. Hemsworth et al[24] and Kranendonk et al[5] similarly reported that low-ranking sows gained less weight than high-ranking sows in a group housing system with floor feeding. If the feeding system could secure individual sows to consume their feed rations, the compromised welfare of low-ranking sows could be largely alleviated. In a previous study with a non-competitive feeding system, it was observed that social rank of sows did not affect weight gain during gestation.[29]

One of the questions this study attempted to answer was whether group size differentially influenced welfare of sows in different social ranks, especially low-ranking sows. Large group sizes combined with low space allowance may result in more injuries from aggression than small groups, probably due to limited opportunities for defeated sows to escape attacking sows.[30] Gonyou and Lang[31] reported that sows in small groups (up to six to eight sows per group) usually form a stable hierarchy. Once the hierarchy is formed, social positions rarely change and aggression among sows is minimal. In contrast, sows in larger groups (20 or more sows per group) usually form an unstable hierarchy which needs to be maintained by constant threats or attacks, resulting in more aggressive interactions. Furthermore, sows in large groups may take longer to establish dominance hierarchy than sows in small groups, causing more skin lesions to sows.[10,13] Barnett et al[32,33] demonstrated that aggression among gilts following mixing was lower in small-group pens than large-group pens. In the current study, due to differences in pen design and composition of pen mates between the large- and small-group pens, effects of group size could not be separated from these confounding factors. When assigned to the study, sows

Table 6: Reasons for culling sows in different social ranks gestated in either large or small pens

	Large pen*			Small pen*			
	HR†	**MR†**	**LR†**	**HR†**	**MR†**	**LR†**	**Total**
Total no. of sows culled (%)‡	7 (22)	5 (12)	9 (28)	1 (6)	2 (12)	1 (6)	25 (16)
No. of sows culled for each reason							
Injuries from fighting	1	3	2	0	0	1	7
Poor reproduction§	3	1	2	0	0	0	6
Abortion	2	1	1	0	0	0	4
Poor milk production	1	0	3	0	0	0	4
Lameness	0	0	1	0	0	0	1
Poor body condition	0	0	0	0	0	0	0
Sickness	0	0	0	0	1	0	1
Died or euthanized	0	0	0	1	1	0	2

* The large pen housed 26 sows, and the small pen housed six sows. Both pens provided equal floor space allowance (1.5 m^2/sow).
† Sows were categorized as high (HR), middle (MR), or low ranking (LR) on the basis of outcomes of aggression at mixing.
‡ Percent of pregnant sows assigned to the study at 5 weeks after breeding, calculated as [no. of sows culled ÷ no. of pregnant sows assigned] × 100.
§ Included sows that returned to estrus, failed to farrow, and farrowed or weaned small litters.

in small-group pens were younger and had lower body weight than sows in large-group pens. This was because sows were sorted by size in small-group pens, with an equal number of pens housing small sows and large sows, so that the ratio of small to large sows assigned to small-group pens was 1:1. However, in large-group pens, the ratio of small to large size was approximately 1:3.5 due to the sow composition of each breeding cohort. The high percentage of small sows allocated to small-group pens resulted in lower body weight and parity of sows at initiation of the study, and these were confounded with effects of group size. As a result, effects of group size were not examined in the current study. Instead, it focused on effects of social rank on the welfare of sows in each group size. It appears that social rank affects the welfare of sows in both groups in a similar pattern. In other words, the welfare of sows seems dictated by social rank in both groups in the current study.

The competitive feeding system used in the current study may lead to uneven body condition of sows, resulting in an elevated incidence of reproductive failures and culling. One of the management strategies to deal with this issue is to sort sows by size so that sows in a pen have similar nutritional needs and competitive ability.[31] In the current study, sorting was conducted only in small-group pens. Coincidently, farrowing rates of low- and high-ranking sows in small group pens were 100% and 94%, respectively, which were higher than 81% and 81% for their counterparts in large-group pens. The high culling rate of low- and high-ranking sows in large-group pens raises a concern about longevity of sows under the housing conditions of this study.

Implications

- In the group-housing system studied, results suggest that social rank similarly affects the welfare of sows in large-group pens (26 sows per pen) and small-group pens (six sows per pen), with poorer welfare in lower-ranking sows, as indicated by more skin lesions, less weight gain, and higher salivary cortisol concentrations.
- To verify these results, long-term studies that involve several gestation cycles and large number of sows are needed.

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Conflict of interest

None reported.

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Table 7: Effects of social rank on farrowing performance of sows*

	Social rank†			
	High	**Middle**	**Low**	***P***
Sows farrowed†	41	53	42	NA
Litter size (no. of piglets/litter)				
Total born	13.5 ± 0.6	13.3 ± 0.6	14.5 ± 0.6	.28
Live born	12.4 ± 0.6	12.4 ± 0.5	13.2 ± 0.6	.49
Stillborn	0.8 ± 0.1	0.6 ± 0.1	0.8 ± 0.2	.28
Mummies	0.2 ± 0.1	0.3 ± 0.1	0.5 ± 0.1	.29
Weaned‡	10.9 ± 0.3	11.2 ± 0.3	10.9 ± 0.3	.62
Piglet pre-weaning mortality (%)§	15.1 ± 2.6	12.8 ± 2.0	12.5 ± 2.1	.68
Piglet weight at weaning (kg)				
Litter weight	76.8 ± 2.2	79.9 ± 2.4	76.8 ± 2.3	.52
Piglet weight	7.1 ± 0.1	7.2 ± 0.1	7.2 ± 0.1	.87
Wean-to-estrus interval (days)	4.9 ± 0.7	5.0 ± 0.7	6.0 ± 0.9	.54

* Gestation pens provided equal floor space allowance (1.5 m^2/sow).
† Sows were categorized as high, middle, or low rank on the basis of outcomes of aggression at mixing in gestation pens.
‡ Piglets were weaned at 3 weeks after birth.
§ Calculated as [no. of piglets that died before weaning ÷ no. of piglets born alive] × 100; may differ slightly because of cross-fostering.
NA = not applicable.

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