Australian Government
Department of Agriculture

Space and Group Size Effects on the Welfare of Grouped Sows Day 8 Observations

Final Report
APL Project 2011/1023

July 2012

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Acknowledgements

This project is supported by funding from Australian Pork Limited and the Department of Agriculture.

The authors wish to acknowledge funding for this research from Rivalea Australia and the University of Melbourne. The technical support of Tracie Storey, Pauline Madrange, Megan Verdon and the Rivalea Research and Innovation Group is gratefully acknowledged.

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Executive Summary

Recent changes in the Australian Model Code of Practice for the Welfare of Animals – Pigs recommend restricting the duration of housing gestating sows in stalls to the first six weeks of gestation and very recently, the Australian pork industry voted to pursue the voluntary phasing out of gestation stalls by 2017. However, international industry experience indicates that the opportunity for group housing to improve sow welfare is presently limited by the high levels of aggression that are commonly observed in newly formed groups of sows after mixing. Thus a better understanding of the effects of floor space allowance, group size, time of mixing and provision of feeding stalls may assist in developing strategies to reliably reduce aggression and stress in group-housed sows. Furthermore, this research is necessary to inform animal welfare standards for sows mixed in groups after mating.

A previous study (APL Project 2193 - The effects of group housing during gestation on sow welfare and reproduction) examined the effects of floor space allowance and group size on the welfare of sows grouped after mating. Effects of space on aggression during feeding on Day 2 post-mixing were found along with effects on stress on the basis of plasma cortisol concentrations (also taken on day 2 post mixing). There was a general decline in both aggression and cortisol concentrations with increasing space from 1.4 m^2/sow to 3 m^2/sow, while there was general increase in farrowing rate with increasing space. Surprisingly, there was no evidence that space affected skin injuries. This current project consisted of completing the video observations of aggression at Day 8 post-mixing that were not completed in the previous project. The results from these observations on aggression at day 8 support those on total cortisol concentrations at days 9 and 51 of treatment and farrowing rate. There were no effects of space on aggression at day 8 which is also reflected in no space effects on cortisol at day 9. Aggression at Day 8 was also not affected by group size.

In conclusion, the results of these two projects indicate that space affects aggression and stress physiology early post-mixing, and reproduction in sows. Based on these effects of space, it is credible to judge that, within the range of sow densities and the feeding system used in this study, sow welfare improves as floor space allowance increases. However, it is difficult to determine what is an adequate space allowance for sows from the present results. Although the results are in accord with a linear decline in cortisol concentrations early post-mixing from 1.4 m^2/sow to 3 m^2/sow, the results are also in accord with a decline in cortisol from 1.4 m^2/sow to 1.8 m^2/sow and no further decline above 1.8 m^2/sow. The size of the experiment has turned out to be insufficient to be able to determine which of these scenarios is more biologically correct. Thus in terms of animal welfare at mixing, it is impossible to give guidance on an adequate space allowance, other than a space allowance of 1.4 m^2/sow is likely to be too small.

It should also be recognized that the effects of space are most pronounced early after grouping. Indeed, it appears that sows in static groups may adapt to reduced space. Nevertheless, in terms of risks to both welfare and productivity, these results highlight the importance of sufficient space in order to reduce aggression and stress at mixing and that the sow's requirement for space appears to be less once the group is well established.

As recommended in the previous project (APL Project 2193 - The effects of group housing during gestation on sow welfare and reproduction), further research is recommended to examine the effects of space allowance in the range of 1.8 to 2.4m^2/sow in more detail. Particular attention should be given to the effects of space and time of mixing relative to mating (days 1 to 4 post-mixing), since this is the period when aggression and stress are likely to be most pronounced and the adverse

effects on reproductive performance are likely. This research should also include an examination of the effects of pen features such as feeding stalls and feeding systems, since these are likely to affect aggression and stress.

Background to Research

There appears to be increasing community concern with society's treatment of animals (Fraser, 2008). Confinement housing of livestock such as those common in modern pig and poultry production appears to be at the forefront of these concerns. In relation to pig housing, the most contentious animal welfare issue is housing of dry (non-lactating) sows. Increasing community concern about confinement housing has led internationally to legislation, consumer and retailer pressure to increase the use of group housing for gestating sows. Housing sows in stalls is being phased out in the European Union by 2013 (Council Directive 2001/88/EC, 2001) and in New Zealand by 2015 (National Animal Welfare Advisory Committee, 2005) except for the first 4 weeks of gestation. Recent changes in the Australian Model Code of Practice for the Welfare of Animals – Pigs recommend restricting the duration of housing gestating sows in stalls to early gestation (PISC (Primary Industries Ministerial Council), 2007).

Industry experience however indicates that the opportunity for group housing to improve sow welfare is presently limited by the high levels of aggression that is commonly observed in newly formed groups of sows after mixing (Velarde, 2007): this aggression, especially if intense and prolonged, may lead to injuries and stress. However, there are few rigorous recommendations in the scientific literature on the design features of sow group housing that reduce aggression (Petherick and Blackshaw, 1987; Arey and Edwards, 1998; Barnett et al., 2001). While the problem of pig aggression has received considerable attention, detailed studies of aggressive behaviour have generally used staged paired encounters or small group sizes. These research settings are very different from commercial settings.

There is evidence of a chronic stress response and reduced reproductive performance if space allowance is insufficient. For example, elevated basal cortisol concentrations have been reported in female pigs with a floor space allowance of 1 m2/pig or less (Hemsworth et al. 1986; Barnett et al. 1992). While the former study indicated that there may be reproductive performance advantages of housing at 3 m2/pig than 2 m2/pig, the physiological criteria indicated no differences between these space allocations. Weng et al. (1998) reported increased aggression and injuries with decreasing space allowance and recommended a space allowance between 2.4 and 3.6 m2/sow for groups of 6 pregnant sows.

There is also limited evidence of effects of group size on sow welfare and reproduction. Barnett et al. (1984, 1986) found that housing sexually mature gilts in pairs resulted in a chronic stress response compared to housing in groups of 4-8 with a similar space allowance. Both large group size (24 vs. 8 gilts) and small group size (3 vs. 9, 17 or 27 gilts) may reduce the expression of oestrus (Christenson and Ford 1979; Christenson and Hruska 1984), while increasing group size and concomitantly decreasing space allowance may also reduce the expression of oestrus in gilts (Cronin et al. 1983). Broom et al. (1995) compared sows in groups of 5 fed in stalls and a group of 38 sows with an electronic feeding station and while there was increased aggression in the larger group, particularly after initial mixing, any differences in aggression and stereotypies had disappeared by the fourth parity. Olsson et al. (1994) reported increased injuries as group size increased. Some limited research by Taylor et al. (1997) has shown varying group sizes, of 5, 10, 20 and 40 sows with a space allowance of 2.0 m2/sow, had no effects on reproductive performance (farrowing rate and litter size). Although aggression immediately after mixing increased as group size increased, the number of lesions during gestation were similar across treatments. In the same study, reducing space allowance for groups of 10 sows from 2.0 to 1.2 m2/sow increased aggression. Further research is required to determine the optimum space allowance and group size for pregnant pigs. There are no data on space allowance/group size interactions for adult female pigs.

A recent Australian Pork Limited-funded project (Project 2193 - The effects of group housing during gestation on sow welfare and reproduction) examined the effects of floor space and group size on aggression on day 2 post-mixing, stress, injury, lameness and reproduction in sows housed in groups during gestation. This current project consisted of completing the video observations of aggression at Day 8 post-mixing that were not completed in the previous project, thus providing valuable information from this extensive data set.

Objectives of the Research Project

The aim of this experiment was to determine the effects of group size and space allowance on the aggressive behaviour of sows sows housed in groups during gestation at 8 days post-mixing using footage collected in a previous study (APL project 2193). The data from these observations will be analyzed with the main data set from the study including variables for stress, immunology, injuries, live weight and backfat changes and reproductive success.

Research Methodology

Materials and Methods

Facilities

This experiment was conducted in a modified breeding and gestation unit in a large commercial piggery in Corowa, NSW, Australia, and commenced in September 2008 and concluded in December 2009. The accommodation building was 61 m long and 19 m wide, with a galvanized roof and adjustable blinds on the sides and overhead water sprinklers that were activated for 3 minutes on and 15 minutes off when the internal temperature exceeded 26°C.

All procedures were conducted with the approval of the Rivalea animal ethics committee.

Animals and Treatments

A total of 3,120 mated sows, in four time replicates (780 sows per replicate) over 13 months were studied. The sows were crossbred (Landrace x Large White) of mixed parity and of good health at the beginning of the study. Sows were inseminated twice and were introduced to the post-mating housing treatments within 1-7 days of insemination.

A 3x6 factorial design was used to examine two main effects imposed post-mating:

1. Group size at 3 levels, 10, 30, 80 sows per pen.
2. Floor space allowance at 6 levels, 1.4m^2, 1.8m^2, 2.0m^2, 2.2m^2, 2.4m^2, 3.0m^2 per sow.

In each of the four time replicates there were 24 groups with 18 treatments as follows: 10 sows @ 1.4m^2/sow-2 groups; 10 sows @ 1.8m^2/sow-2 groups; 10 sows @ 2.0m2/sow-2 groups; 10 sows @ 2.2m2/sow -2 groups; 10 sows @ 2.4m^2/sow -2 groups; 10 sows @ 3.0m^2/sow-2 groups; 30 sows @ 1.4m^2/sow; 30 sows @ 1.8m^2/sow; 30 sows @ 2.0m^2/sow; 30 sows @ 2.2m^2/sow; 30 sows @ 2.4m^2/sow; 30 sows @ 3.0m^2/sow; 80 sows @ 1.4m^2/sow; 80 sows @ 1.8m^2/sow; 80 sows @ 2.0m^2/sow; 80 sows @ 2.2m^2/sow; 80 sows @ 2.4m^2/sow; and 80 sows @ 3.0m^2/sow. Two groups of 10 sows were included in each of the treatments for the group size of 10 in each time replicate in order to sample sufficient animals for the physiological and injury variables in each treatment and to obtain similar variance in the treatments in each time replicate (that is, to allow 20 sows to be sampled in each treatment). Thus there were 24 pens in total within the facility, one pen of each space allowance for the group sizes of 30 and 80 and 2 pens of each space allowance for the group size of 10.

The 24 experimental pens were located within the same area of the accommodation building (see Figure 1). The three group sizes were located down the length of the building, but because of construction limitations, the groups of 80 were located in the two outside rows of pens and the groups of 10 and 30 were located in the two inner rows of pens. The length of the building was divided into 3 sub-replicates so that, within a sub-replicate, the outer and inner rows each contained an 80 group size treatment and each of the 2 inner rows contained both a 10 group size (2 pens) and a 30 group size treatment. The inner and outer row pens were 5.47 and 5.96 m deep and the width of the pens were varied to provide the space allowances of 1.4m^2, 1.8m^2, 2.0m^2, 2.2m^2, 2.4m^2 and 3.0m^2 per sow. Each pen had concrete floors with 50% slatted at the rear of the pens. Drop feeders evenly suspended across the width of each pen (2 drop feeders per 10 animals) were used to deliver the feed, which was delivered four times per day (hourly from 0700 h) providing a total of 2.5 kg/sow/day of a commercial diet (13.1 MJ/kg DM, and12.8% crude protein). Water was provided *ad libitum* via nipple drinkers attached to the back wall over the slatted flooring.

Within each replicate on each of the three alternate Mondays in a 6-week period, a sample of 260 sows was assigned to a sub-replicate, mated during the previous week. Within a sub-replicate sows were randomly allocated to treatments within that sub-replicate (Figure 1). Sows were housed post-weaning and inseminated in a morning/afternoon insemination routine in stalls, before being firstly, randomly selected for study and then randomly allocated to treatment. Within 1 week of insemination, sows were moved to their allocated housing treatment and, unless culled for reproductive failure, injuries or health, remained in their treatment pens for 105 days, after which they were relocated to a farrowing house for the remaining few days of gestation. Introduction to the allocated housing treatment was considered day 1 of treatment.

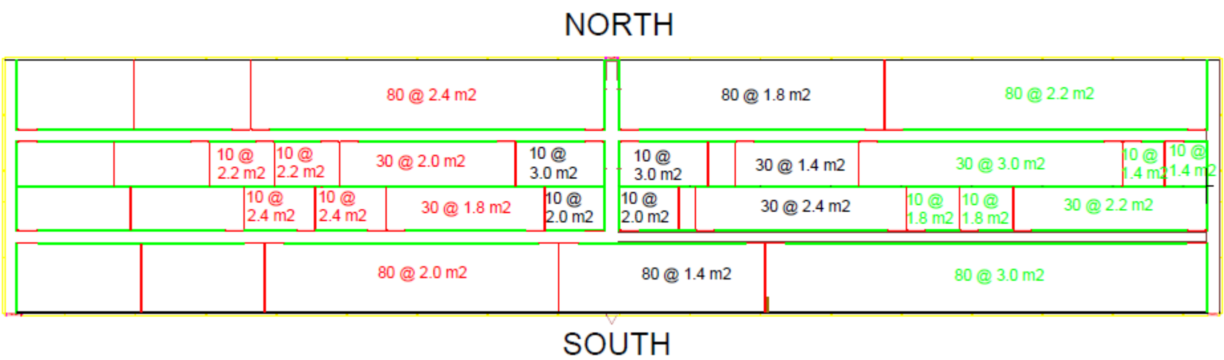

Figure 1: Layout of experimental pens in the accommodation building.

Sows commenced treatment (within 1-7 days of insemination) in replicate 1 from the 22nd September to 20th October 2008 (spring season in southern hemisphere, in replicate 2 from 5th January to 2nd February 2009 (summer), in replicate 3 from 20th March to 18th May 2009 (autumn) and in replicate 4 from 3rd August to 31th August 2009 (winter).

Regular oestrus checks for returns to service were conducted as well as a pregnancy test using ultrasonography 5 weeks after mating. All sows that returned to oestrus, those that tested negative at the pregnancy test and those that were culled for injury or poor health were recorded and removed from treatment pens. Sows removed from treatment due to reproductive failure or injury were not replaced in the groups by other sows.

Aggressive Behaviour at Feeding

Feed was delivered to each pen four times per day (hourly from 0700 h) using overhead drop feeders evenly spaced across the width of each pen at a ratio of one drop feeder per 5 sows. In order to observe aggressive behaviour at feeding, 3.6 mm infra red CCTV cameras were installed overhead near a drop feeder to record behaviour at the time that feed was distributed on the solid floor below the drop feeder. The focal range of each camera matched the dimensions of the smallest pen size (i.e. 10 sows with 1.4 m^2/sow) and thus each camera covered a floor area of 14 m^2 allowing a constant floor area to be recorded at each feed drop. Cameras were installed over each pen allowing pigs feeding below two feeders to be recorded. Thus apart from the smallest pen where one camera could cover the floor area of 14 m^2 under two feeders, two cameras were installed over other pens so that the area under two feeders was recorded. The cameras continuous recorded from 0600-1700 h for 3 days commencing at days 2 and 8 of treatment.

From the digital video records, continuous observations were conducted to measure the number of bouts of aggressive behaviour in the 30 min following each feed drop on day 2 and the first feed drop on 8. A 'bout criterion interval' of 5 s was chosen to separate one bout of aggressive behaviour from another bout of the same behaviour by an individual sow. Behaviours recorded as aggressive behaviours were slashes, butts, pushes and bites and these aggressive behaviours were distinguished from other tactile interactions with pigs (e.g. licking) on the basis that the former were associated with avoidance or retaliation by one pig as a consequence of the interaction. Only aggressive interactions in which the head of the pig (defined as extending from the snout to the ears) displaying the aggressive behaviour was clearly visible were recorded. The identity of each sow was not recorded since aggression at the level of the group was the main focus.

In order to compare aggressive behaviour between treatments, aggressive behaviour per pig observed in the field of view of each camera for 30 min after the feed drop was calculated as follows. The average number of pigs in the field of view was recorded at regular intervals so that the number of bouts of aggression could be expressed on the basis of the average number of pigs in the field of view during the observations. Point or instantaneous scans at 30 s intervals during each 5 min block of footage were used to count the number of pigs in each scan, providing an estimate of the average number of pigs in the field of view during each 5 minute block of the observation period. Thus using this estimate of the average number of pigs in the field of view over each 5-minute segment, the frequency of bouts of aggression after each feed drop was calculated on a "per pig in field of view" basis for each 5-min block observed. The average frequency of aggression during the observed feed drops on days 2 and 8 was collated and analyzed for each pen.

Other Measurements

The methodology for the other measurements, skin injuries, physiology (cortisol and white blood cell count), live weight, backfat and reproductive performance were previously described in the Final Report for project 2193 ("The effects of group housing during gestation on sow welfare and reproduction", Final Report APL project 2193, April 2011).

Statistics

Each measurement was analysed using a series of restricted maximum likelihood (REML) mixed model analyses that, as well as treatment effect combinations being examined, a priori included a fixed effect for replicate and random effects for row within replicate, sub-replicate within replicate and the interaction between row and sub-replicate within replicate. In all REML analyses, the experimental unit was all sows being measured in a pen within a replicate. To reduce skewness of the residuals, prior to the REML analyses, several measurements were either square root or logarithmically transformed (Table 1). For measurements that were calculated using all sows, rather than just focus animals, a dot histogram of residuals from a saturated treatment model was drawn for each group size, so that the possibility of different amounts of random variation with group size could be examined. In no case was there any large change in the amount of residual variation with group size.

For each measurement four REML models were fitted with different treatment effects included, namely (1) no treatment effects at all, (2) additive effects of group size and a linear response to the amount of space per sow, (3) additive effects of group size and a quadratic response to the amount of space per sow, and (4) a saturated treatment model of all combinations of group size and space per sow. From these models, Wald F tests were calculated for (1) group size after adjusting for an additive quadratic response to space per sow, (2) a linear response to space for sow adjusted for an additive effect of group size, (3) a quadratic response to space for sow adjusted for an additive effect of group size, and (4) any effect of group size and space per sow combinations in addition to additive effects of group size and the quadratic response to space per sow. These tests allowed a parsimonious treatment model to be selected for each measurement. Wald chi-square tests were occasionally substituted for the Wald F tests, when the Wald F tests could not be numerically calculated (Table 1).

Results

The four REML models fitted with different treatment effects for each measurement and the most parsimonious REML models that were selected are presented in Table 1. Note that these data refer to those reported in the previous APL project (APL Project 2193 - The effects of group housing during gestation on sow welfare and reproduction) and the data on aggression at day 8, studied in the present project.

Effect	Group Size (GS)	Linear response to sow space (SpaceVar)	Quadratic response to sow space (SpaceVarSq)	Any further treatment effect	Treatment effects selected
Terms adjusted for	SpaceVar + SpaceVarSq	GS	GS +SpaceVar	Effects in previous 3 columns	
Aggressive behaviour at feeding					
Aggression, day 2[1]	0.48	**0.029**	0.34	0.29	**SpaceVar**
Aggression, day 8[1]	0.50	0.72	0.29	0.61	None
Physiology					
Total cortisol, day2	0.48	**0.0089**	0.052	0.13	**SpaceVar**
Total cortisol, day 9	0.35	0.23	0.47	**0.013**	None
Total cortisol, day 51	0.27	0.12	0.19	0.90	None
Free cortisol, day2[2]	0.41	**0.036**	0.080	0.13	**SpaceVar**
Free cortisol, day 9[2]	0.45	0.085	0.57	**0.0010**	None
Free cortisol, day 51[2]	0.94	0.76	0.14	0.78	None
Neutrophil-lymphocyte ratio, day 2[2]	**0.0092**	0.99	0.85	0.48	**GS**
Neutrophil-lymphocyte ratio, day 9[2]	0.18	0.94	**0.0080**	0.80	**SpaceVar + SpaceVarSq**
Neutrophil- lymphocyte ratio, day51[2]	**0.027**	0.063	0.28	0.76	**GS**
Injuries					
Fresh injuries, day 2[1]	057	0.59	0.19	0.70	None[5]
Fresh injuries, day 9[1]	**0.045**	0.099	0.91	0.12	**GS**
Fresh injuries, day 23[1]	0.40	0.37	0.99	0.14	None
Fresh injuries, day 51[1]	0.56	0.62	**0.031**	0.69	None
Total injuries, day 2[1]	0.50	0.39	0.32	0.41	None
Total injuries, day 9[1]	**0.0017**	0.36	0.44	0.17	**GS**
Total injuries, day 23[1]	**0.0046**	0.67	0.81	**$3.3*10^{-5}$**	**GS**
Total injuries, day 51[1]	**0.00059**[6]	0.17[5]	0.020[5]	0.94[4]	**GS**
Culled for non reproductive	0.05	0.10	0.86	0.42	None

reasons[3]					
Reproductive performance					
Born alive	0.66	0.13	0.71	0.15	None
Still born	0.56	0.94	0.22	0.97	None
Farrowing rate	0.77	**0.012**	0.37	0.74	**SpaceVar**
Live weight and backfat					
Change in backfat P2	0.12	**0.028**	**0.012**	0.56	**SpaceVar + SpaceVarSq**
Change in live weight	**0.013**	0.80	0.15	0.63	**GS**

Table 1: P values of tests for choosing parsimonious models, of treatment effects, for each measurement.

[1, 2, 3]: Data transformed square root, log10 and arc sine, respectively, prior to statistical analysis.

[4]: The random main effect for row was fixed to be 0, so as to achieve numerical convergence.

[5]: Model chosen is a constant value irrespective of group size and space per sow

[6]: Used Wald χ^2 test because the calculation of F test numerically failed.

Aggressive Behaviour at Feeding

The most parsimonious model that predicted aggression at feeding on day 2 included a linear response to space (Table 1). As shown in figure 2, in which this relationship is depicted, a general decline in aggression occurred with increasing space.

There was no relationship found between group size and space and aggression at feeding on day 8.

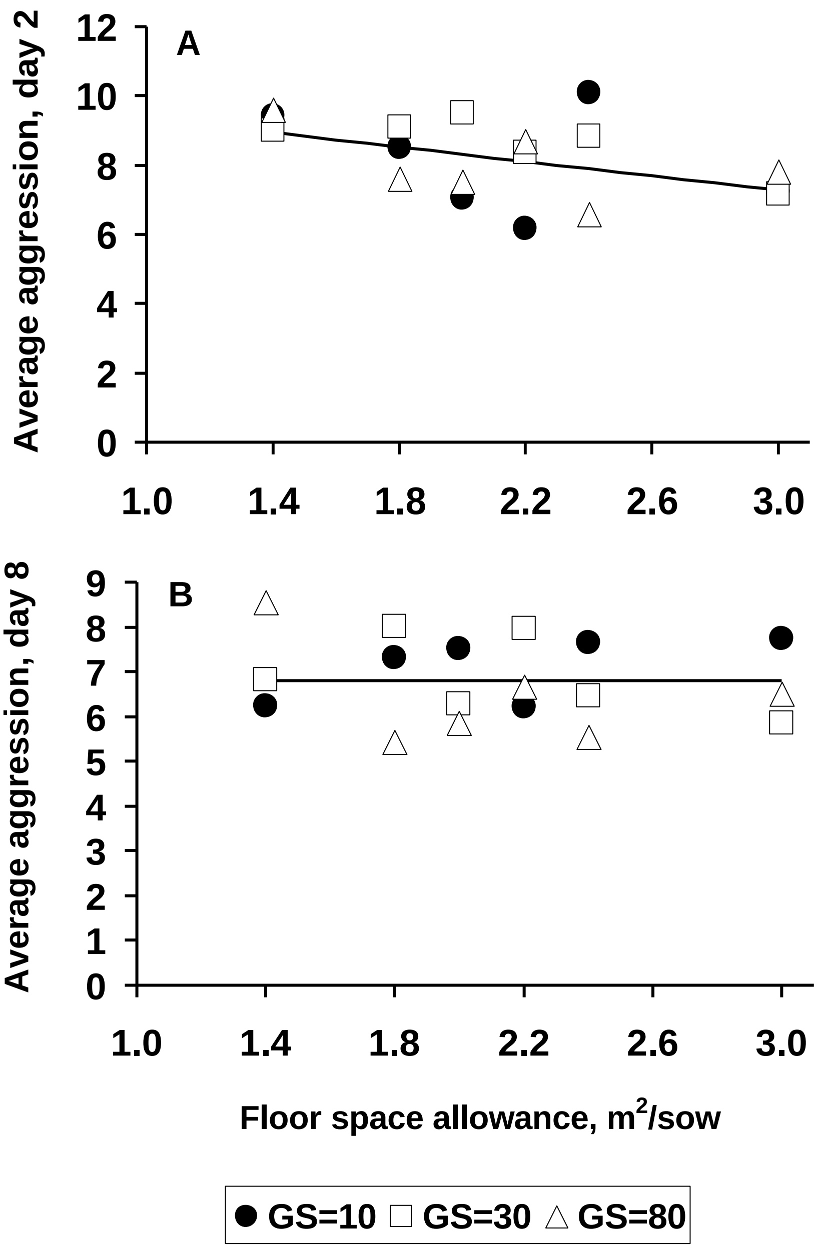

Figure 2: Predicted values of aggression at day 2 (A) and day 8 (B) as a function of space per sow.

Other Main Measurements

The most parsimonious model that predicted plasma total cortisol concentrations at day 2 included a linear response to space (Table 1). A general decline in total cortisol concentrations occurred with increasing space. As shown in Table 1, there were no relationships found between space and total cortisol concentrations at days 9 and 51. There were also no relationships found between group size and total cortisol concentrations at days 2, 9 and 51.

There were no relationships found between the treatments of group size and space and litter size (born alive), and stillborn piglets (Table 1). However, there was a relationship found between the treatments of group size and space and farrowing rate (Table 1). The most parsimonious model predicting farrowing rate included a linear response to space: farrowing rate increased with increasing floor space.

Discussion

One of the most consistent effects found in the previous project (APL Project 2193 - The effects of group housing during gestation on sow welfare and reproduction) were those of floor space allowance on several parameters early in the treatment period. A key finding was the effects of space on aggression at feeding at day 2 of treatment, both total and free cortisol concentrations at day 2 of treatment and farrowing rate. For all four variables, there was a linear relationship with space: there was a general decline in aggression and both total and free cortisol concentrations with increasing space, while there was general increase in farrowing rate with increasing space. There was no evidence that space affected total cortisol concentrations at days 9 and 51 of treatment. Surprisingly, there was no evidence that space affected fresh or total injuries at day 2 of treatment or later when there was evidence of space effects on aggression at day 2.

The effects of space on aggression at day 2 found in APL project 2193 were accompanied by corresponding space effects on cortisol and farrowing rate. The results from the present project (APL Project 2011/1023) on aggression at day 8 support those on total cortisol concentrations at days 9 and 51 of treatment and farrowing rate in that there were no effects of space on aggression at day 8.

These results on the effects of space on aggression and stress in grouped sows in these two projects are generally supported by a number of previous experiments on gilts (Hemsworth et al., 1986; Barnett et al., 1992; Barnett, 1997), however as distinct from these other experiments, space effects were most apparent most pronounced early after grouping. While this suggests that sows in static groups may adapt over time to reduced space, the mechanism involved and the role of pregnancy in this are unknown. There is a need to examine the effects of reducing space during gestation since this effect may offer the opportunity for 'staged-gestation penning' in order to provide increased space immediately after insemination.

Implications & Recommendations

In conclusion, the results of the previous project (APL Project 2193 - The effects of group housing during gestation on sow welfare and reproduction) and the present project indicate that space affects aggression, stress physiology and reproduction in sows. While the effects of space on aggression and stress physiology were found early in treatment, the effects of space on farrowing rate highlight that stress might be biologically important in the period shortly after mixing in the formation of a static group of sows that have been recently inseminated. Furthermore, the results indicate that the effects of space are most pronounced early after grouping. Indeed, it appears that sows in static groups may adapt to reduced space. Nevertheless, in terms of risks to both welfare and productivity, these results highlight the need to reduce aggression and stress at mixing. Clearly, further research is required to examine the effects of space allowance in the range of 1.8 to 2.4m^2/sow in more detail. Particular attention should be given to the effects of space early post-insemination since this is the period when aggression and stress are likely to be most pronounced. Research should also include an examination of the effects of pen features, such as feeding stalls and feeding systems, since these are likely to affect aggression and stress.

Intellectual Property

Information generated at this stage of the RD&E process, while creating intellectual property value, does not lead to patentable outcomes.

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