INFLUENCE OF SOCIAL STATUS ON THE WELFARE OF SOWS IN STATIC AND DYNAMIC GROUPS

N E O'Connell*‡, V E Beattie* and B W Moss†

* Agricultural Research Institute of Northern Ireland, Large Park, Hillsborough, Co Down, BT26 6DR, UK

† Department of Food Science, Queen's University Belfast, Newforge Lane, Belfast BT9 5PX, UK

‡ Contact for correspondence and requests for reprints: niamh.o'connell@dardni.gov.uk

Abstract

*Animal Welfare 2003, **12**: 239-249*

Forty-eight Large White × Landrace multiparous sows were mixed into twelve groups of four animals after their piglets were weaned. These groups were defined as static, with no animals being added to or removed from the groups after their formation. Aggressive and submissive behaviours were recorded continuously for 9 h after the sows were mixed, and the sows were assigned high or low social status on the basis of their relative aggressiveness and success in aggressive interactions. After five weeks, each static group was mixed into a dynamic group of 40 ± 2 sows for an 11-week period. Three static groups (ie 12 animals) at a time were added to the dynamic group at three-week intervals; the same number of animals was removed at these time-points in order to maintain the group number at 40 ± 2. Injury levels increased significantly with the transition from static groups to the dynamic group ($P < 0.001$). Sows with low social status had lower bodyweights ($P < 0.001$) and higher injury levels one week after mixing into static and dynamic groups ($P < 0.01$). Social status did not significantly affect salivary cortisol levels. Sows with low social status were positioned lower in the feed order, determined using an electronic feeder ($P < 0.001$), and tended to be displaced from the feeder queue more often ($P < 0.1$) in the dynamic group. Sows with low social status were also displaced from the drinker more often than high-ranking sows in the dynamic group ($P < 0.01$). This may have led to the greater frequency of drinking behaviour shown by low-ranking sows ($P < 0.05$). Sows with low social status were observed less often in the kennel areas than were the high-ranking sows in the dynamic group ($P < 0.05$), suggesting that they were denied access to the prime lying areas. The results suggest that the welfare of sows is negatively affected by low social status in both small static and large dynamic groups.

Keywords: *animal welfare, dynamic groups, social status, sows, static groups*

Introduction

Recent amendments to European pig welfare legislation mean that producers throughout the European Union will be required to group-house sows by 2013 (Council Directive 2001/88/EC amending Directive 91/630/EEC Laying Down Minimum Standards for the Protection of Pigs). There are, however, welfare problems associated with group-housing of sows, mainly because of high levels of aggression and injury (Arey & Edwards 1998). Researchers have therefore aimed to improve the welfare of sows in groups through investigating different group-housing systems (Broom *et al* 1995; Jensen *et al* 2000). Two such systems that have been investigated are 'static' and 'dynamic' group systems (Durrell 2000). In static groups, sows remain together throughout gestation. In dynamic groups, on the other hand, sows that are due to farrow are continually replaced by those that have just been mated. Evidence suggests that this continual replacement of animals in dynamic groups leads to higher levels of aggression and poorer welfare than in static groups (Simmins 1993).

In addition to welfare differences between group-housing systems, evidence suggests that welfare levels fluctuate within any given group-housing system and that these fluctuations are related to social factors in the group (Mendl *et al* 1992; Brouns & Edwards 1994; Andersen *et al* 1999). This suggests that in addition to investigating the effect of different group-housing systems on the welfare of groups of sows, we should also investigate the welfare of individuals within a given group-housing system. The aim of the present study was to assess the effect of social status on the welfare of sows in static and dynamic groups.

Methods

Design and treatments

The effect of social status on the welfare of sows was assessed using a longitudinal design with twelve replicates. Each replicate comprised a group of four sows that remained together for a five-week period and was then mixed into a dynamic group of 40 ± 2 sows for an 11-week period.

Animals

Forty-eight Large White × Landrace sows were used in this experiment. The sows were on average fifth parity, and no sow was less than second parity. The sows were bred at the Agricultural Research Institute of Northern Ireland. All experimental procedures were carried out under a Home Office Licence granted under the Animals (Scientific Procedures) Act 1986.

Housing and management

Piglets were weaned from the sows when they were 24 ± 2 days of age, and the sows were then weighed and mixed into static groups of four animals (day 1). These groups were balanced for weight in order to minimise within-group weight variation. The static groups were housed in service pens (5.0 × 2.4 m) containing four voluntary cubicles (2.0 × 0.6 m each), a slatted exercise area (1.5 × 2.4 m) and a kennel area with a solid floor (1.5 × 2.4 m). The sows were fed once per day in the cubicles by dump feeding. The sows were served by artificial insemination on day 5 and were transferred into the dynamic group on day 33.

Static groups were added to the dynamic group at three-week intervals, with three static groups (twelve sows) being added at a time. Twelve sows were removed from the dynamic group three days prior to the static group-members being added to the dynamic group.

In the dynamic group, the sows were housed in a split-yard system (18.2 × 7.8 m) with three kennels in yard 1 and three kennels in yard 2. Each of these kennels measured 4.7 × 2.9 m. Both yards contained a slatted exercise and drinking area which measured 7.5 × 3.1 m in yard 1 and 10.7 × 2.5 m in yard 2.

Yard 1 was separated from yard 2 by gates and an electronic feed station which allowed individual feeding of sows. The entrance to the feed station was in yard 1 and the exit was in yard 2. Once a sow entered the feed station she was prevented from returning to yard 1 or from re-entering the feed station until the following morning. Each sow was fed her ration over a 13 min period, after which the exit gate opened automatically to allow the sow to leave the feeder; simultaneously, an entry gate opened to allow the next sow to enter the feeder. The feed cycle started at approximately 0800h when all sows were moved from yard 2 to yard 1. All sows used in this study had experience with the electronic feeding system. Sows were offered 3 kg day^{-1} of a cereal/soya-based diet supplying 13.3 MJ digestible energy per kilogram air-dry diet until artificial insemination, and then 2.5 kg day^{-1} of the same diet for the rest of the experimental period.

Both static and dynamic groups were housed in the same portal-frame uninsulated building with concrete block walls and a corrugated steel roof. In both treatments, the sows were exposed to a day/night cycle, with full lighting 0800h–1700h and dimmed lighting for the remainder of the time. The sows were also exposed to natural lighting through clear plastic panels inserted in the roof. The experiment was carried out during the autumn/winter period and the mean temperature range in the insulated kennel areas was 13–20°C.

Measurements

Bodyweight and age

Each sow was weighed immediately prior to being mixed into the static group. Age was also recorded.

Social status

Each static group of sows was videotaped continuously in real time for the first 9 h after the group had been mixed together. Aggressive and submissive behaviours (Table 1) were recorded continuously during this period, along with the identities of the perpetrator and recipient of these behaviours. Social status was calculated for each sow according to the following equation:

$$\frac{\text{Number of sows dominated}}{\text{Number of sows dominated} + \text{number of sows which dominated her}} \times 100$$

Table 1 Ethogram of aggressive and submissive behaviours recorded from sows at the time of mixing into static groups.

Behaviour	Description
Aggressive	
Fighting	Engaging in mutual pushing, parallel or perpendicular, and ramming the opponent with the head in rapid succession with or without biting.
Threatening	Facing or lunging the head toward another sow and the other sow actively withdrawing.
Headthrusting	Ramming or pushing another sow with the head, with or without biting, in an event that is not recorded as part of a fight.
Biting	Aggressively biting any part of another sow without headthrusting.
Chasing	Actively pursuing another sow.
Submissive	
Losing fight	Receiving bites, headthrusts or chases from another sow at the end of a fight without retaliating.
Fleeing	Actively moving away from another sow following an aggressive interaction.
Withdrawing	Actively moving away from another sow without any obvious interaction having taken place.
Body turning	Turning the body by 180° to protect head and ears.

A sow was characterised as being dominant to a second sow if she performed at least two aggressive behaviours toward that second sow that were reciprocated with submissive behaviours. In certain cases, both sows performed aggressive behaviour toward each other. For a sow to be characterised as dominant she must have performed at least four times more aggressive behaviour than the submissive sow.

Sows with a social status value greater than or equal to 50% (26 sows) were assigned high social status, and sows with a social status value less than 50% (22 sows) were assigned low social status.

Injuries

Injuries were recorded one day and one week after the sows were mixed into both static and dynamic groups. In addition, injuries were recorded during the last week in the static group, in order to allow for differentiation between injuries sustained in the static group and those sustained in the dynamic group. These were measured on 12 separate areas of the body: head, right ear, left ear, right shoulder, left shoulder, back, right flank, left flank, right hindquarter, left hindquarter, vulva, and tail. Injuries were measured on a scale of 0 to 3, defined as follows: 0 = no injuries; 1 = one to three injuries; 2 = four to six injuries; 3 = more than six injuries. Injuries were defined as areas of raised skin with redness, or of broken skin with or without redness and measuring ≥ 1 cm in length. Injury scores were summed to give a total injury score for each animal (maximum possible score = 36). In addition, the number of areas of the body that sustained injuries was also recorded for each animal.

Salivary cortisol

Saliva samples were taken from each sow on the day of mixing into the static group and one week later, and one day and one week after mixing into the dynamic group. Samples were collected from sows in a predetermined randomised order, which meant that some samples were taken from sows as they were resting and others from sows that were active. All samples were taken between 1300h and 1500h. Samples were not taken from sows immediately after drinking but at least 5 min later. Each sample was collected using a custom-made 'Salivette' (Sarstedt Ltd, Germany), which contained a cylindrical piece of cotton fitted inside a plastic tube. To collect the sample, the cotton was secured to a 30 cm long plastic cable-tie and placed into the side of the sow's mouth. The sow was allowed to chew on the cotton for 1 min. The cotton was then returned to the plastic tube, which was placed in an ice box. Samples were centrifuged for 5 min at 3000 rpm within 1 hour of sampling, and saliva was stored at –20°C.

Salivary cortisol was measured using an enzyme-linked immunosorbent assay (ELISA, DRG Instruments GmbH, Germany). Samples were analysed according to the manufacturer's instructions, with the exception that samples and calibration standards were incubated and shaken for 1 h at room temperature immediately after being added to the plate wells in order to increase absorbency.

Resident pen behaviour

The behaviour of each of the sows was recorded continuously for 5 min on the first, second and fourth afternoons after being added to the dynamic group, and then once per week for the following 10 weeks in the dynamic group. All observations took place between 1300h and 1600h. The ethogram, shown in Table 2, included both social and exploratory behaviours.

Table 2 Ethogram of resident pen behaviours recorded from sows in the dynamic group.

Behaviour	Description
Nosing another sow	Sniffing, touching with nose or rubbing any part of another sow.
Being nosed	Being the recipient of the above behaviour.
Manipulating another sow	Nibbling, sucking or chewing any part of another sow (except tail and vulva).
Being manipulated	Being the recipient of the above behaviour.
Biting another sow	Aggressive biting of any part of another sow.
Being bitten	Being the recipient of the above behaviour.
Tail-biting another sow	Nibbling, sucking or chewing the tail of another sow.
Being tail-bitten	Being the recipient of the above behaviour.
Vulva-biting another sow	Nibbling, sucking or chewing the vulva of another sow.
Being vulva-bitten	Being the recipient of the above behaviour.
Fighting	Engaged in mutual pushing, parallel or perpendicular, and ramming another sow with the head, with or without biting, in rapid succession.
Headthrusting	Ramming another sow with the head (with or without biting).
Moving a sow from lying area	Nosing or biting another sow which then leaves its lying area.
Being moved from lying area	Being the recipient of the above behaviour.
Moving a sow from feeder queue	Nosing or biting another sow which then leaves the feeder queue.
Being moved from feeder queue	Being the recipient of the above behaviour.
Moving a sow from drinker	Nosing or biting another sow which then leaves the drinker.
Being moved from drinker	Being the recipient of the above behaviour.
Being inactive while alert	Sitting, standing or lying inactive with eyes open.
Lying with eyes closed	Lying inactive with eyes closed.
Exploring ground	Sniffing or nosing any part of the floor of the pen.
Exploring fixtures	Sniffing, nosing, sucking or chewing any object which is part of the pen (eg walls, railings).
Chewing	Sham-chewing or chewing particles other than feed (eg faeces).
Locomotion	Any whole-body movement, including walking.
Feeding	Sow in feed station.
Drinking	Sow drinking from water nipple.
Eliminating	Defecation or urination.
Other	When the sow is not performing any of the listed behaviours or is hidden from the observer's view.
Nothing	When the sow is not being the recipient of any behaviour from another sow.

Feed order

The order in which each sow went through the electronic feeder was recorded by video-camera twice during the first week and then once per week for the following 10 weeks in the dynamic group. The feed order for each sow was then expressed as a proportion of the number of sows in the group, a low value indicating that the sow went through the feeder early in the feed order.

Location and activity state

The location of each of the sows in the dynamic group, in terms of whether they were in kennels or on the slatted part of the pen, was recorded in one instantaneous scan each week during the treatment period. In addition, the activity state of each of the sows, in terms of whether they were standing, sitting or lying, was also recorded at this point. The frequency of being located in the kennel or slatted areas was expressed as a proportion of the number of scans in which the sow was not in the feeder, and activity state was expressed as a proportion of the total number of scans.

Statistical analysis

The data were analysed using Genstat 5 (Lawes Agricultural Trust 1989). Residual maximum likelihood (REML) analysis was used to assess the effect of social status on injury rates and salivary cortisol levels in the static and dynamic groups, on behaviour and feed order in the dynamic group, and on bodyweight and age of the sows. This analysis was carried out using social status as the fixed model and replicate as the random model. All variation in REML analysis is expressed as the standard error of the mean (SEM). Paired *t*-tests were used to assess whether increases in total injury score and in the number of injured body parts between the first week in the static group and the first week in the dynamic group, and between the last week in the static group and the first week in the dynamic group, were significantly greater than zero. Kappa coefficients were calculated to assess the consistency in feed order within each replicate between different weeks in the dynamic group.

Results

Bodyweight and age

Sows that had high social status when mixed into the static group also had a significantly greater bodyweight at this stage than sows with low social status (high 268.3 kg, low 249.5 kg; SEM 3.78 kg, $P < 0.001$). There was no significant difference in age between animals of high and low social status (high 1144 days, low 1024 days; SEM 53.2 days).

Injuries

Results from injury measurements are given in Table 3. Sows with low social status were injured on a significantly greater number of body areas than sows with high social status 1 week after mixing into both static and dynamic groups ($P < 0.01$). Sows with low social status also had a significantly higher total injury score 1 week after mixing into static groups ($P < 0.01$) and a significantly higher number of injured body areas 4 weeks after mixing into static groups ($P < 0.05$).

Paired *t*-tests showed that the increase in total injury scores and in the number of injured body areas between the first week in the static group and the first week in the dynamic group, and between the last week in the static group and the first week in the dynamic group, was significantly greater than zero ($P < 0.001$).

Salivary cortisol

Salivary cortisol levels did not differ significantly between animals of high and of low social status on the day of mixing into the static group (high 7.1 nmol l^{-1}, low 8.1 nmol l^{-1}; SEM 0.95 nmol l^{-1}) or 1 week later (high 12.8 nmol l^{-1}, low 12.6 nmol l^{-1}; SEM 1.96 nmol l^{-1}). Similarly, social status did not significantly affect salivary cortisol levels on the day after mixing into the dynamic group (high 9.3 nmol l^{-1}, low 7.5 nmol l^{-1}; SEM 1.4 nmol l^{-1}) or 1 week later (high 6.2 nmol l^{-1}, low 6.5 nmol l^{-1}; SEM 1.5 nmol l^{-1}).

Feed order

Kappa coefficients showed a high level of consistency in the feed order between different weeks in the dynamic group (Table 4). Therefore, an average feed order was used in comparisons between animals of high and low social status.

Sows with a high social status had a significantly lower feed order, and therefore went through the electronic feeder earlier, than sows with low social status (high 0.4, low 0.6; SEM 0.05, $P < 0.001$).

Table 3 Influence of social status on injury levels of sows at different periods after mixing into static and dynamic groups. NS, not significant.

Parameter	High social status	Low social status	SEM	*P*
Static group				
Injury score (1 day)	2.5	2.9	0.47	NS
No. of injured body areas (1 day)	2.2	2.6	0.41	NS
Injury score (1 week)	2.9	6.2	0.78	<0.01
No. of injured body areas (1 week)	2.3	4.9	0.55	<0.001
Injury score (4 weeks)	4.0	5.5	0.80	NS
No. of injured body areas (4 weeks)	3.1	4.4	0.45	<0.05
Dynamic group				
Injury score (1 day)	7.6	9.0	0.98	NS
No. of injured body areas (1 day)	5.1	6.2	0.46	<0.1
Injury score (1 week)	8.3	10.2	1.24	NS
No. of injured body areas (1 week)	5.1	7.0	0.44	<0.01

Table 4 Kappa coefficients between the feed order within groups of four sows in a dynamic group of 40 (± 2) sows over an 11-week observation period (P* < 0.05; ***P* < 0.01; ****P* < 0.001).**

Week	1	2	3	4	5	6	7	8	9	10	11
1	—										
2	0.095	—									
3	0.127*	0.311***	—								
4	0.179**	0.206**	0.492***	—							
5	0.022	0.233**	0.400***	0.244**	—						
6	0.159**	0.067	0.400***	0.413***	0.311***	—					
7	0.270***	0.044	0.200**	0.318***	0.133*	0.397***	—				
8	0.381***	0.178**	0.467***	0.444***	0.222**	0.333***	0.413***	—			
9	0.200**	0.033	0.400***	0.267***	0.100	0.400***	0.178*	0.222**	—		
10	0.311***	0.133	0.467***	0.511***	0.133	0.267***	0.333***	1.000***	0.333***	—	
11	0.556***	0.000	0.222	0.556***	-0.333	0.000	0.557***	0.556***	0.333	0.556***	—

Resident pen behaviour

Results from observations of resident pen behaviour are given in Table 5. Sows with low social status were observed drinking more often ($P < 0.05$) and were also displaced from the drinker more often than sows with high social status ($P < 0.01$). In addition, sows with low social status tended to be displaced from the feeder queue more often than sows with high social status ($P < 0.1$).

Location and activity state

Sows with high social status in the dynamic group were observed in the kennel areas in a higher proportion of scans than were sows with low social status (high 0.80, low 0.67; SEM 0.045, $P < 0.05$). There was no significant effect of social status on the proportion of scans in which sows were standing (high 0.35, low 0.49; SEM 0.061), sitting (high 0.02, low 0.02; SEM 0.013) or lying (high 0.63, low 0.50; SEM 0.065).

Table 5 Influence of social status on frequency per minute of performance of behaviours in a dynamic group. NS, not significant.

Behaviour	High social status	Low social status	SEM	*P*
Nosing another sow	0.339	0.377	0.0477	NS
Manipulating another sow	0.011	0.003	0.0043	NS
Biting another sow	0.009	0.008	0.0034	NS
Tail-biting another sow	0.001	0.001	0.0007	NS
Vulva-biting another sow	0.001	0.001	0.0009	NS
Fighting	0.001	0.002	0.0010	NS
Headthrusting another sow	0.026	0.014	0.0063	NS
Moving a sow from lying area	0.003	0.002	0.0014	NS
Moving a sow from feeder queue	0.002	0.005	0.0017	NS
Moving a sow from drinker	0.004	0.003	0.0021	NS
Being inactive while alert	1.008	1.054	0.0931	NS
Lying with eyes closed	0.357	0.272	0.0529	NS
Exploring ground	0.299	0.372	0.0461	NS
Exploring fixtures	0.374	0.467	0.0599	NS
Chewing	0.770	0.918	0.1025	NS
Locomotion	0.586	0.790	0.0887	NS
Feeding	0.008	0.013	0.0033	NS
Drinking	0.041	0.076	0.0122	<0.05
Eliminating	0.013	0.016	0.0033	NS
Other	0.474	0.665	0.0582	<0.05
Being nosed	0.219	0.225	0.0228	NS
Being manipulated	0.001	0.001	0.0006	NS
Being bitten	0.001	0.007	0.0025	NS
Being tail-bitten	0.000	0.000	—	NS
Being vulva-bitten	0.000	0.000	—	NS
Being headthrusted	0.018	0.029	0.0058	NS
Being moved from lying area	0.003	0.002	0.0018	NS
Being moved from feeder queue	0.003	0.016	0.0050	<0.1
Being moved from drinker	0.001	0.008	0.0017	<0.01
Nothing	0.435	0.468	0.0244	NS

Discussion

The relationship shown here between social status and bodyweight confirms the results of previous studies of group-housed sows (Arey 1999). Increased bodyweight may enable sows to attain higher social status by making it physically easier to dominate penmates in aggressive encounters (Jensen & Yngvesson 1998). In addition, subordinate sows may be less likely to fight back when the opponent is larger and therefore perceived to have greater fighting ability (Rushen 1987). One of the benefits to an individual sow of high social status

https://doi.org/10.1017/S0962728600025665 Published online by Cambridge University Press

was a reduction in injury levels and therefore an improvement in welfare (Signoret 1983). This effect was evident not only in the dynamic group, but also in the static group, where significantly lower levels of injury were shown overall. This suggests that social status influences the welfare of sows in systems that engender both high and low levels of aggression. The apparent higher levels of aggression after mixing into the dynamic group may have resulted from the larger group size and the dynamic nature of the group (Arey & Edwards 1998). The fact that welfare appeared poorer after mixing into dynamic rather than static groups agrees with previous research (Simmins 1993).

The increased levels of injury shown in low-ranking sows after mixing into static and dynamic groups were not reflected in increased salivary cortisol levels. This is in contrast to previous research which found a positive relationship between rates of sustaining aggression-related injury and physiological stress levels in gilts (Olsson & Svendsen 1997). It is possible that too few saliva samples were taken at each time point in the present study to enable accurate measurement of differences in stress levels. Previous observations have shown that single or occasional measurement of cortisol does not provide an accurate measure of stress because of natural fluctuations in cortisol levels (Broom 1988). However, the increased human contact associated with the taking of more samples at each time point may also have influenced salivary cortisol levels (Hemsworth *et al* 1993). In addition, evidence suggests that cortisol levels are influenced by factors such as activity level (Broom & Johnson 1993). The fact that some saliva samples were collected from sows while they were resting and others from sows while they were active may have masked the effect of social status on cortisol levels in the present study. These factors support the use of more categorical measures of welfare, such as injury level (Signoret 1983), when investigating loose-housed sows.

Sows that were assigned low social status in static groups were consistently positioned in the second half of the feed order in the dynamic group, which agrees with previous research (Hunter *et al* 1988). The fact that sows with low social status tended to be displaced from the feeder queue more often than higher-ranking animals suggests that they were motivated to feed but were prevented from doing so. This may have negative welfare implications, especially as the sows were being fed approximately one third of what they would have eaten if fed to appetite (Walker & Beattie 1994). Sows with low social status were also displaced from the drinker more often than high-ranking animals. This may have led to the increased frequency of drinking behaviour that was observed in these animals. These results suggest that sows with low social status have a reduced ability to hold a resource, such as the feeder or drinker. This reduced resource-holding ability corresponds with previous research showing that sows with low social status had difficulty gaining access to feed in competitive floor-feeding systems (Brouns & Edwards 1994).

The fact that sows with low social status were observed less often in the kennel areas suggests that they were denied access to these prime lying areas by the higher-ranking sows, as seen in previous studies (Spoolder 1998). This agrees with the observations of reduced resource-holding ability in low-status sows, which may be related to reduced aggressiveness and/or reduced bodyweight in low-ranking animals (O'Connell & Beattie 1999). However, it is also possible that lower-ranking sows chose to remain in the poorer areas of the pen in order to avoid contact with higher-ranking animals (Moore *et al* 1993). The fact that sows with high and low social status were observed lying for similar amounts of time in the present study suggests that sows with low social status used the slatted area for resting as well as for activity.

Animal welfare implications

The present study shows that the welfare of sows fluctuates within as well as between different group-housing systems. The results suggest that low-ranking sows in groups may require extra monitoring to ensure that they achieve adequate access to resources and do not suffer from excessive aggression. Individual electronic feeders may be of particular benefit to these sows when housed in large groups, as they ensure that sows receive the correct feed allowance.

Acknowledgements

We wish to thank the technicians and stockpersons of the Pig Unit of the Agricultural Research Institute of Northern Ireland for excellent technical assistance and care of the animals. We also wish to thank Dr D J Kilpatrick and Mr A Gordon for help with statistical analysis.

References

Andersen I L, Bøe K E and Kristiansen A L 1999 The influence of different feeding arrangements and food type on competition at feeding in pregnant sows. *Applied Animal Behaviour Science 65*: 91-104

Arey D S 1999 Time course for the formation and disruption of social organisation in group-housed sows. *Applied Animal Behaviour Science 62*: 199-207

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

Broom D M 1988 The scientific assessment of animal welfare. *Applied Animal Behaviour Science 20*: 5-19

Broom D M and Johnson K G 1993 *Stress and Animal Welfare.* Chapman & Hall: London, UK

Broom D M, Mendl M T and Zanella A J 1995 A comparison of the welfare of sows in different housing conditions. *Animal Science 61*: 369-385

Brouns F and Edwards S A 1994 Social rank and feeding behaviour of group-housed sows fed competitively or *ad libitum*. *Applied Animal Behaviour Science 39*: 225-235

Durrell J L 2000 *Improving the welfare of group housed sows.* PhD Thesis, Queen's University Belfast, UK

Hemsworth P H, Barnett J L and Coleman G J 1993 The human–animal relationship in agriculture and its consequences for the animal. *Animal Welfare 2*: 33-51

Hunter E J, Broom D M, Edwards S A and Sibly R M 1988 Social hierarchy and feeder access in a group of 20 sows using a computer-controlled feeder. *Animal Production 47*: 139-148

Jensen K H, Sørensen L S, Bertelsen D, Pedersen A R, Jørgensen E, Neilsen N P and Vestergaard K S 2000 Management factors affecting activity and aggression in dynamic group housing systems with electronic sow feeding: a field trial. *Animal Science 71*: 535-545

Jensen P and Yngvesson J 1998 Aggression between unacquainted pigs — sequential assessment and effects of familiarity and weight. *Applied Animal Behaviour Science 58*: 49-61

Lawes Agricultural Trust 1989 *Genstat 5 Reference Manual.* Clarendon Press: Oxford, UK

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

Moore A S, Gonyou H W and Ghent A W 1993 Integration of newly introduced and resident sows following grouping. *Applied Animal Behaviour Science 38*: 257-267

O'Connell N E and Beattie V E 1999 Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. *Animal Welfare 8*: 269-279

Olsson A C and Svendsen J 1997 The importance of familiarity when grouping gilts, and the effect of frequent grouping during gestation. *Swedish Journal of Agricultural Research 27*: 33-43

https://doi.org/10.1017/S0962728600025665 Published online by Cambridge University Press

Rushen J 1987 A difference in weight reduces fighting when unacquainted newly weaned pigs first meet. *Canadian Journal of Animal Science 67*: 951-960

Signoret J P 1983 General conclusions. In: Smidt D (ed) *Indicators Relevant to Farm Animal Welfare* pp 245-247. Martinus Nijhoff: Dordrecht, The Netherlands

Simmins P H 1993 Reproductive performance of sows entering stable and dynamic groups after mating. *Animal Production 57*: 293-298

Spoolder H A M 1998 *Effects of food motivation on stereotypies and aggression in group housed sows*. PhD Thesis, Wageningen Agricultural University, The Netherlands

Walker N and Beattie V E 1994 *Welfare of sows in loose housed systems*. 67th Annual Report. Agricultural Research Institute of Northern Ireland: Hillsborough, Co Down, UK