EFFECTS OF AGGRESSIVE CHARACTERISTICS OF INDIVIDUAL SOWS AND MIXING STRATEGIES ON THE PRODUCTIVITY AND WELFARE OF GROUP-HOUSED GESTATING SOWS

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Executive Summary

There appears to be increasing community concern with its treatment of animals (Fraser, 2008). Confinement housing of livestock, in particular housing of gestating sows, appears to be at the forefront of these concerns, which in turn has led to legislative, consumer, and retailer pressure to increase the use of group housing of gestating sows. International industry experience, however, indicates that the opportunity for group housing to improve sow welfare can be limited by high levels of aggression that are commonly observed in newly formed groups of sows after mixing (Velarde, 2007).

Sow aggression poses a significant risk to sow welfare and productivity. Although the problem of pig aggression has received considerable attention, detailed studies of aggressive behaviour have generally utilized staged paired encounters or small group sizes, with many using young immature pigs, not sows. Furthermore, while age, experience and genetics affects variation between pigs in aggressive behaviour, group composition may also affect how individuals behave in groups.

The aims of this project were to (1) develop predictive tests of aggressive behaviour of the sows in groups and (2) to determine whether the composition of groups, particularly in terms of the aggressive behaviour of individual sows, is related to the welfare and reproductive performance of both the individual and the group as a whole.

Three experiments were conducted in this project to address these aims. In the first experiment, 720 female pigs were used to examine the relationship between two potential predictive tests of aggression and sow aggression when mixed in single-parity groups at the first and second gestations. The two tests involved measuring the behavioural response of pigs to both unfamiliar similar-aged gilts or sows and a fibreglass model sow. Both stimuli were located in a stall adjacent to the stall in which the test pig was introduced for 2 min. Behavioural observations such as latency to contact and bouts and frequency of contact by the test pig with each stimulus were recorded from video records. Gilts at 24 weeks of age, mated gilts and mated first-parity sows were tested in these behavioural tests before introduction to and mixing in their gestation pens. Records were taken on aggression (delivered and received) at feeding on the second day after mixing (Day 2) and an 'aggression index' (the ratio of aggression delivered to the aggression delivered and received) was calculated for each female in each gestation.

Significant relationships were found between the behavioural response of pigs in the two tests and the aggression index at Day 2 of grouping. These significant correlations were of moderate magnitude and indicated that sows that were quicker to interact and interacted more with the stimulus in the behavioural tests had a higher aggression index in groups based on aggression delivered relative to aggression both delivered and received. The correlations were most pronounced in sows than gilts, suggesting that aggressive behaviour is strongly influenced by experience. The repeatability of the most predictive variable of aggression when mixed, the latency to snout contact with the model sow, was moderate from the first to second parity. However, its repeatability from selection to the first and second parity was poor. Used with caution, this predictive test may be useful in providing an insight into the impact of group composition on aggression and welfare of both the individual and the group as a whole. The value of this predictive test as a selection tool requires further evaluation.

The second experiment was comprised of two parts utilising 200 female pigs in their first and second gestations. Part 1 examined the repeatability of individual sow aggressive behaviour while Part 2 examined the relationship between aggression and welfare in these group-housed females.

In Part 1 of this second experiment, the aggression index on Day 2 of grouping was correlated with the index on Days 9 and 51 in both gestations, although the relationships were stronger in the second gestation than the first. In addition, the aggression index on Day 2 of Gestation 1 was moderately but significantly correlated with that on Day 2 in Gestation 2, although this correlation was weaker than within gestation relationships. Thus sow aggressive behaviour is repeatable within gestations but less so between gestations and, while it is most likely that there are both genetic and experiential effects, aggression of individual sows is likely to be affected by the aggressive behaviour of other sows in the group.

In Part 2 of this second experiment, the relationships between aggression index and welfare outcomes were examined using both partial correlations controlling for gestation and comparisons of female pigs classified as 'Dominant' if they delivered more aggression than they received (aggression index > 0.5), 'Subdominant' if they received more aggression than they delivered (aggression index >0, <0.5) and 'Submissive' if they delivered no aggression (aggression index=0).

While the aggression index was not correlated with either total or fresh injuries on Day 2 of grouping, it was significantly and negatively correlated with total and fresh injuries on both Days 9 and 51 of gestation, with the relationships on Day 51 being stronger than those on Day 9.There were no significant correlations between aggression index and cortisol on Days 2, 9 or 51. However, the aggression index on Day 2 was significantly and positively correlated with both weight gain during gestation and the number of piglets born alive.

While there were similar relationships between aggressive classification of the female pigs and pig welfare in Gestations 1 and 2, there were also some differing effects. Dominant female pigs gained more weight in Gestation 1 but not 2. There were no differences between classifications on fresh or total injuries on D2, however dominant female pigs had fewer injuries on D9 in both gestations, and submissive female pigs had the most injuries on D51 in both gestations. Furthermore, subdominant female pigs had higher stress, based on plasma cortisol concentrations, on D2 only in the second gestation. These results indicate that female pigs that engage in aggression at mixing and gain dominance have less injuries and possibly less stress. Their increased weight gain and litter size may be due to increased feed intake through priority access to feed and/or less stress. Furthermore, there is evidence that the most aggressive sows had higher litter sizes (born alive). Thus the aggressive behaviour of the female pig early after grouping is an important determinant of her subsequent welfare and productivity.

Experiment 3 examined the effect of group composition on aggression within the group. Manipulating the group composition based on predicted sow aggressive behaviour to form groups of high or mixed aggression had no effect on aggression delivered or received, aggression index, injuries, cortisol concentrations or reproductive performance. This contrasts with previous studies in young immature pigs, however both the social behaviour and social experience of sows are markedly different to that of younger pigs. Thus it appears that although sows vary in terms of individual aggressive characteristics, the tendency to show aggression is less important than the behaviour of others in the group. When fighting has significant costs, such as when sows are housed with older sows, otherwise aggressive sows may show flexibility in their use of aggression, opting out of aggressive interactions.

In conclusion, this research indicates that variation exists in groups of sows between individuals in terms of their aggression and consequently welfare and productivity. While group housing of sows allows all more freedom of movement, exploration and socialization, a few may suffer from excessive aggression, injuries and stress. Consequently it raises the question of what welfare priority should be attached to different classes of animals: the majority, the most vulnerable, the most productive, etc.

Furthermore, this research indicates that the behavioural response of female pigs to a fibreglass model sow ('aggressive motivation' test) before mixing is related to aggressive behaviour of females mixed in groups in the first and particularly second gestations. This behavioural test, based on the response of female pigs to a social stimulus, appears to be a useful predictive test of the aggressive behaviour of sows mixed in groups and appears moderately repeatable when used on sows experienced with grouping. Furthermore, these project results also indicate that, while individual aggressive behaviour is repeatable within gestations, it is less repeatable between gestations. The reduced repeatability between gestations is likely to be due to both experience and group composition affecting the aggressive behaviour of individual sows. Indeed, mixing females either of predicted high levels of aggression (homogenous groups) or mixing randomly (heterogenous groups) did not affect aggression delivered or received, aggression index, injuries, cortisol concentrations or reproductive performance of the group. The aggressive behaviour of female pigs appears flexible, changing with both social experience and group composition. Discussions with geneticists are required to explore firstly, the potential of this 'aggressive motivation' test relative to other recent and on-going developments in this area and secondly, the need for further development of this 'aggressive motivation' test in a genetic improvement programme. This predictive test of aggressive motivation also appears to be a useful research tool to study the effects of group composition in terms of homogeneity or heterogeneity of aggressive behaviour in sows.

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1. General Introduction

The welfare of production animals is becoming increasingly important to the general community, consumers and producers of animal products. One issue that is receiving significant attention is the housing of gestating sows. Public concern regarding the confinement of sows in gestation stalls has increased pressure on legislators and the livestock industry to restrict the use of stall housing in favour of housing sows in groups (Standing Committee on Agriculture and Research Management, Australia 2007; EU Commission, EU 2007; Department of Environment, UK 2007). However, while group-housing sows allow for increased movement and social interactions, the occurrence of high levels of aggression between sows, particularly at mixing and feeding, may increase injury and stress thus compromising sow welfare and productivity.

The biological fitness of an animal can be reduced if its behavioural and physiological responses to a challenging environment or event are insufficient to counteract any adverse effects caused by that environment or event (Broom, 1986, 2000). However, intraspecific variation in the behavioural and physiological responses of animals to stress means that some individuals may cope better than others under stress (Benus, 1990; Lagerspetz, 1961, 1964, 1975; Koolhaas et al., 2007). In addition, while welfare is defined in terms of the individual, it is often studied on the basis of the group as a whole. Consequently, the animals with the most severely compromised welfare may remain undetected in groups.

The literature indicates that pigs vary in individual aggressive characteristics (Ruis et al., 2001, 2002; Verdon et al., 2011; Mendl et al., 1992; Geverink et al., 2002, 2004; Krauss and Hoy, 2001; Mount and Seabrook, 1973). There is limited evidence that in the sexually mature female pig, variations in aggressive behaviour are related to an individual's welfare (Mendl et al., 1992; Zanella et al., 1998; Verdon et al., 2011). However, it is not possible to confidently protect vulnerable sows in commercial group housing systems until first, the factors affecting vulnerability, such as pen design features, group composition, experience and genetics, are well understood, and second, if developments in understanding and applying this knowledge do not progress sufficiently quickly, those most vulnerable sows at risk are identified prior to exposure to aggression.

Aggressiveness in pigs is a moderately heritable trait (Turner et al., 2008, 2009; D'Eath et al., 2009) and DNA markers have been identified in two genes that also have multiple and consistent associations with stress responsiveness and aggressive behaviour (Muráni et al., 2010). Therefore, there may be opportunity to test for aggression in the sow prior to mixing. However, pigs are social animals, and as such the social group is likely to also have an impact on an individual's behaviour. The distribution of aggressive individuals within groups of wild sows may vary in a way that achieves maximum social harmony by stabilising the social structure of the group. Indeed, recent studies have shown that aggression in groups of young pigs is lower when composed of mixed aggression animals, rather than groups of uniform aggression (Erhard et al., 1997; Hayne & Gonyou, 2006, D'Eath et al., 2010).

As noted by Lay et al. (2011) and others, the normal social behavioural repertoire of modern livestock comprises ancestral behaviour patterns exhibited when animals were provided with adequate space and access to diverse resources. The extent to which these behaviour patterns are expressed by the animal in the modern production system is likely to depend not only on their housing, including characteristics of their group-mates and access to resources, but also on genetics, previous experience including during rearing, possibly environmental conditions during embryonic development, and epigenetic effects.

The aims of this project are to examine (1) possible predictive tests of 'aggressive motivation' of sows that are related to the aggressive behaviour of the sows when housed in groups and (2) whether the composition of groups, in terms of the aggressive behaviour of individual sows, is related to the welfare and reproductive performance of both the individual and the group as a whole.

2. Experiment 1 - Predicting aggression

Experiment 1 - Introduction

International industry experience indicates that the opportunity for group housing to improve sow welfare may be limited by high levels of aggression that are 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. There is limited evidence that sows are more aggressive when mixed in the first week after insemination than when mixing 5 weeks post-insemination (Hemsworth et al., 2006; Strawford et al., 2008). There is also limited evidence that mixing sows directly after weaning affects sow sexual behaviour, particularly subordinate sows (Pedersen et al., 1993, 2003). While further research is clearly required to reduce sow aggression, the design of the group housing system (such as floor space, group size, frequency of grouping, feeding system and feed intake and diet), animal factors (such as familiarity, experience, genetics and parity) and stockmanship are all likely to affect aggression, injuries and stress in group-housed sows (Arey and Edwards, 1998; Barnett et al., 2001; Spoodler et al., 2009; Bench et al., 2013a,b).

There is also evidence that agonistic behaviour of individual sows may affect their welfare in groups. Sows of low success in displacing other sows in the group had higher concentrations of salivary cortisol and were more responsive to an ACTH challenge, both indicative of a chronic stress response, than sows of high or no success (Mendl et al., 1992). Furthermore, the low success sows had lighter piglets than the other two categories of sows. Similarly, Nicholson et al. (1993) reported that, compared to sows of high or no success, socially intermediate sows showed signs of stress, such as elevated cortisol concentrations and reduced natural T killer-cell activity and had lower farrowing rates and smaller litter sizes. Sows that show little aggression when subsequently mixed spend less time feeding and have more injuries than sows that show higher levels of aggression (Verdon et al., 2011).

There is also evidence that the composition of the group in terms of aggressiveness may affect the overall welfare of the group. Groups of young pigs of varying aggression (high and low), as assessed on the basis of the individual's attack latency in a resident-intruder test, displayed less aggression immediately after mixing than grouping pigs of similar aggression (either high or low) (Erhard et al., 1997b). Furthermore, skin injuries were highest in groups of high aggression. Similar effects were also found when young pigs were housed in groups of mixed aggression in comparison to uniform groups (Ruis et al., 2002; D'Eath et al., 2009).

Thus while factors such as increased floor space and provision of feeding stalls reduce aggression and stress in group-housed sows, it is clear that a better understanding of the effects of the composition of the group, particularly the aggressive behaviour of individual sows, may have important implications for the welfare of the group as a whole. For example, the opportunity arises to assemble groups that perform well in terms of overall welfare based on the composition of the group if (1) the composition of the group in terms of aggressiveness of its individuals affects the overall levels of aggression, injury and stress in the group and (2) this behavioural characteristic is stable over time and/or is heritable. Thus while group housing of sows allows all more freedom of movement, exploration and socialization, a few may suffer from excessive aggression, injuries and stress. As Fraser (2003) suggests, in this case, we need to decide what priority to attach to different classes of animals: the majority, the most vulnerable, the most productive, etc.

Participation in aggression post-mixing and the injuries caused have been found to be of moderate heritability in pigs (h^2 = 0.17 to 0.24, Lovendahl et al., 2005; h^2 = 0.22, Turner et al., 2006a). As recognized by Turner et al. (2006), selective breeding has the potential to reduce aggression at little implementation cost. However, since selection may result in correlated changes in other traits of welfare or economic significance, further studies on the opportunities for selection to reduce aggression, as well as continued efforts to find economically viable and effective non-genetic solutions to aggression, are required (Turner et al., 2009).

Animal breeders need to be able to use tools that can be tested on very large populations. Thus new breeding tools must be practical at large-scale levels of phenotyping. However, measuring sow aggression in groups is difficult. Assessing aggression on the basis of an individual's attack latency in a resident-intruder test is impractical on large numbers of animals as well as risking injury and stress to the participants. The frequency of skin injuries is commonly used as an animal-based indicator of reduced welfare (Barnett and Hemsworth, 2009). Turner et al. (2006) found reciprocal fighting to be highly heritable in growing pigs. In groups of growing pigs the total numbers of injuries 24-hours after mixing are related to the amount of time a pig spent in reciprocal and non-reciprocal aggression (Turner et al., 2006). However, aggression and injuries relationships are not well documented in sows.

A recent experiment showed moderate and consistent relationships between the short-term behavioural response of sows in individual stalls to an unfamiliar older sow and aggression when subsequently mixed in groups (Chow, 2010). In this experiment, recently-inseminated test sows that were quick to interact with unfamiliar sows delivered more aggression when subsequently mixed in groups (of 10 with 2.1 m^2/sow at 40 days post-insemination). These preliminary results suggest that the behavioural response of sows to an unfamiliar social stimulus may usefully predict sow aggression when mixed in groups. The difficulty in using a stimulus sow in such a test is lack of control over the behavioural response of the stimulus sow, which may not only be affected by the behaviour of the test sow but may also affect the behaviour of the test sow. Thus an additional test using a fibre-glass model sow was used in the present study on the assumption that the shape of a sow may be sufficient to elicit a behavioural response in a naive test sow that may be similar at least in the short term to that displayed to other sows that show a neutral response to the test sow.

The aim of this experiment was to develop predictive tests of 'aggressive motivation' of sows that are related to the aggressive behaviour of the sows when housed in groups. The hypothesis was that the behavioural response of female pigs to a social stimulus is predictive of their aggressive behaviour when mixed in groups.

Experiment 1 - Material and Methods

Animals and housing

This experiment was conducted in a gestation unit, specifically renovated for this research, in a large commercial piggery in southern, NSW, Australia, and commenced in October 2010 and concluded in February 2012. This experimental 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 animal procedures were conducted with prior institutional ethical approval under the requirements of the NSW Prevention of Cruelty to Animals Act 1985 in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organization/Australian Animal Commission *Code of Practice for the Care and Use of Animals for Scientific Purposes.*

The female pigs studied were crossbred (Landrace x Large White) of mixed parity and of good health at the beginning of the study. Animals were inseminated twice and were introduced to groups within 1-7 days of insemination. Gilts were housed in groups until detected in oestrus from week 32, when they were then transferred to stalls for insemination. Sows were housed from weaning in stalls. Gilts and sows when detected in oestrus were inseminated twice (morning/afternoon insemination routine). Following insemination but before grouping, gilts and sows were tested in a series of behaviour tests.

In order to study 200 female pigs in the first and second gestation, four cohorts of 180, 22-week old gilts (720 gilts in total) at 3 week intervals were selected using the standard piggery protocol for breeding gilts based on reproductive, mammary and skeletal soundness. From 22 weeks of age until 31 weeks of age, the gilts were housed in groups of 30 (space allowance of 1.4 m^2/gilt). At 31 weeks of age gilts were transferred to the gestation building and housed in groups of 60 until insemination. Once detected in oestrus, gilts were housed in stalls for insemination. Weaned first-parity sows were also housed in stalls for insemination. Both inseminated gilts and first-litter sows after being tested in a series of behavioural tests were housed in single-parity groups of 10 (space allowance of 1.8m^2/sow) during their first and second gestations.

The group pens during gestations had partially slatted floors with a solid cement lying and feeding area and a slatted dunging area. Each pen was fitted with 2 over-header feed droppers and one drink nipple. Gilts and sows were allocated 2.5 kg/sow/day of a standard commercial gestation pelleted diet (13.1MJ/kg DM, and 12.8% protein) delivered onto the floor in four feeding bouts (approximately 07:00, 08:00, 09:00 and 10:00 h) via over-header feed droppers. Gilts and sows remained in these groups for the remainder of the gestation.

Behaviour tests

Gilts at 24 weeks of age and mated gilts and mated 1st parity sows were tested within 1 week of insemination. Using a specifically designed arena (Fig. 1) in the gestation facility, the behavioural response of the animals to both unfamiliar similar-aged female pigs and a model sow and their response to exit from this setting were studied. Pairs of recently-inseminated study animals (gilts or first litter sows) individually housed in stalls were randomly chosen and introduced in sequence to the start boxes in the arena (Fig. 1) for 15 s, the adjacent stalls for 2 min and finally the stalls on either side of the model sow for 2 min. The tests were conducted as follows.

Behavioural response to unfamiliar gilt/sow test

This test consisted of introducing two unfamiliar gilts or sows to adjacent stalls and measurements collated from video records were:

- Latency to snout contact - interval from commencement of test to the test animal's snout entering the space of the adjacent stall (i.e., stall containing the other test animal);

- Bouts of snout contact - number of times the test animal's snout entered the space of the adjacent stall;
- Duration of snout contact - total duration of time that the test animal's snout entered the space of the adjacent stall.

Behavioural response to model sow

This test consisted of introducing animals to a model sow in adjacent stall and measurements collated from video records were:

- Latency to snout contact - interval from commencement of test to the test animal's snout entering the space of the adjacent stall (i.e., stall containing the other test animal);
- Bouts of snout contact - number of times the test animal's snout entered the space of the adjacent stall;
- Duration of snout contact - total duration of time that the test animal's snout entered the space of the adjacent stall.
- Bouts of tactile snout contact – number of times the test animal's snout physically touched the model sow. tHis measure of tactile snout contact was not possible to measure in the unfamiliar gilt/sow test because it was sometimes difficult to identify the deliverer of the contact.

In the week following insemination, mated gilts and mated 1st parity sows were tested in these behavioural tests before introduction to and mixing in their gestation pens.

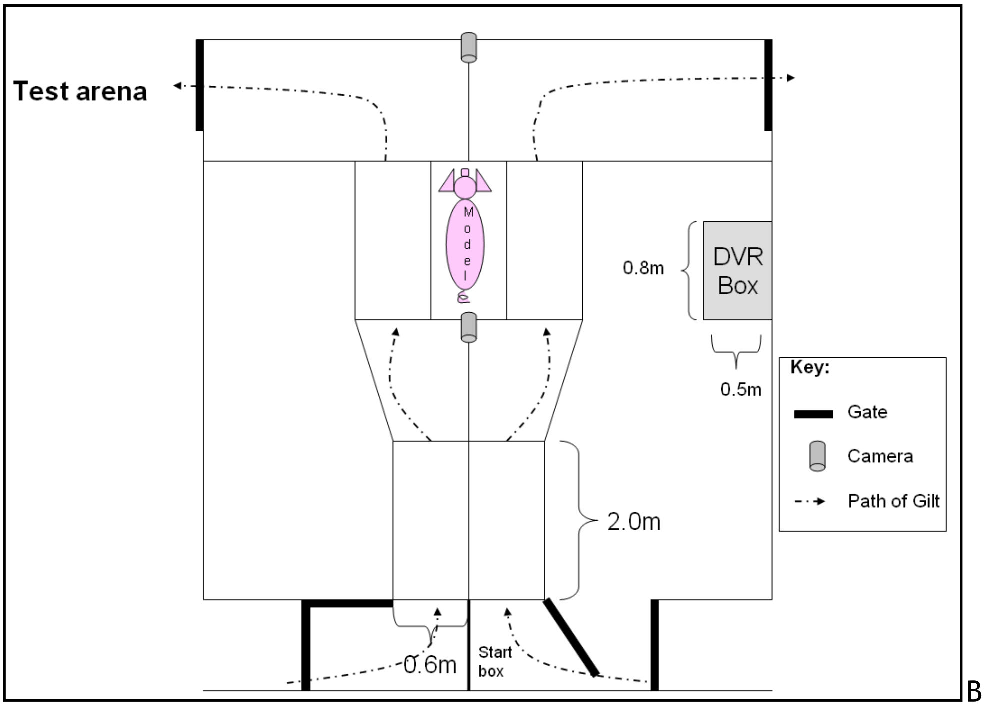

Figure 1 - Test arena used to assess the behavioural response of sows to another sow and a model sow.
Behavioural response to an unfamiliar sow was conducted in the first pair of stalls and the behavioural response to a model sow was conducted in the second set of stalls

Aggressive behaviour post-mixing in Gestations 1 and 2

After testing in the behavioural test, mated gilts and mated 1st parity sows were mixed in groups of 10 (space allowance of 1.8m²/sow) and the following measurements were conducted in these first and second gestations. Since aggression between group-housed sows that are restrictively fed is most pronounced early after mixing and when feeding or accessing feeding areas (Arey and Edwards, 1998; Barnett et al., 2001; Bench et al., 2013), aggressive behaviour was observed on the second day after mixing. One 3.6-mm infra red CCTV (focal range $14m^2$) was installed overhead near a feeder to record behaviour at the time that feed was distributed on the solid floor below the drop feeder and cameras continuously recorded on Day 2.

From the video records, aggressive behaviours as defined in Table 1 were measured for 30 min after each of four feed drops on Day 2. Fights were classified as aggressive interactions involving the same pair of animals that exceed 5 s, and were recorded as one bout of aggression delivered and received for both individuals in the fight and for every 5 s lapsed. Only when the full heads of both animals were clearly in the field of view were aggressive behaviours recorded. The numbers of aggressive behaviours delivered and received by each pig during the observation periods were measured and from these data, the ratio of aggression delivered to the total number of aggressive interactions (i.e., aggression delivered/(aggression delivered + aggression received)), which is labelled the aggression index, was calculated for each individual sow.

Table1 - Ethogram of behaviours classified as aggressive behaviour (from Samarkone and Gonyou, 2009).

Behaviour	Description
Parallel pressing	Pigs stand side by side and push with shoulders against each other, throwing the head against the neck or head of the other
Inverse parallel pressing	Pigs face front to front and then push their shoulders against each other, throwing the head against the neck and flanks of the other.
Head to body knocking	A rapid thrust upwards or sideways with the head or snout against any part of the body behind the ears. Most of the knocks are performed against the front half of the receiver. The performers mouth is shut.
Head to head knocking	A rapid thrust upwards or sideways with the head or snout against the neck, head or ears of the receiver. The performer's mouth is shut.
Bite	A pig delivers a knock with the head against the head, neck or body of the other pig with the mouth open.
Fights	One or a combination of above aggressive behaviours that exceeds 5 s.

Statistics

Spearman correlation coefficients (SPSS statistical package, SPSS 17.0, SPSS Inc., Chicago, Illinois, USA) were used to examine the associations between 7 variables measured in the behavioural test prior to grouping and the aggression index at Day 2 of grouping in parities 1 and 2. For gilts tested at 24 weeks of age, only 1 variable was measured (latency to snout contact with the model sow) and this was examined in relation to the animal's aggression index in groups in Gestations 1 and 2. Because on time limits in measuring the behavioural response of 720 gilts in the unfamiliar gilt and model sow tests, only the latency to snout contact with the model sow, which was shown to be well correlated for mated gilts and sows with the aggression index (see results), was the only variable measured at 24 weeks.

Experiment 1 - Results

The Spearman correlation coefficients between the variables measured in the behavioural test prior to grouping gilts in the first gestation and the aggression index of gilts at Day 2 of grouping in the first gestation are presented in Table 2. None of the behavioural variables in the unfamiliar gilt test were correlated with the aggression index in gilts, although the correlation between duration of snout contact and the aggression index approached significance (P=0.054). Two of the behavioural variables in the model sow test were correlated with the aggression index. Both the bouts and duration of snout contact were positively correlated (P<0.05) with the aggression index: increased snout contact in the unfamiliar gilt test was associated with a higher aggression index.

Table 2 - Spearman correlation coefficients (*r*) between the behavioural variables in the behavioural test prior to grouping and the aggression index at Day 2 of grouping in Gestation 1 (n=200).

Variables		Aggression index	
Unfamiliar gilt/sow test		***r***	**P value**
	Latency to snout contact	-0.018	0.804
	Bouts of snout contact	0.030	0.672
	Duration of snout contact	0.136	0.054
Model sow test			
	Latency to snout contact	-0.118	0.095
	Bouts of snout contact	**0.163**	0.021
	Duration of snout contact	**0.158**	0.025
	Bouts of tactile snout contact	0.056	0.431

Two variables in each of the unfamiliar sow and in model sow tests measured in the behavioural test prior to grouping sows in the second gestation and the aggression index of sows at Day 2 of grouping in the second gestation were correlated (Table 3). Latency to snout contact and bouts of snout contact in the unfamiliar sow test were correlated (P<0.05) with the aggression index. A short latency to snout contact and frequent bouts of snout contact were associated with an increased aggression index. Furthermore, the latency to snout contact and bouts of tactile snout contact in the model sow test were correlated (P<0.05) with the aggression index: short latencies of snout contact and frequent bouts of tactile snout contact were associated with a higher aggression index.

Table 3 - Spearman correlation coefficients (*r*) between the behavioural variables in the behavioural test prior to grouping and the aggression index at Day 2 of grouping in parity 2 sows (n=200).

Variables		Aggression index	
Unfamiliar gilt/sow test		***r***	**P value**
	Latency to snout contact	**-0.179**	0.011
	Bouts of snout contact	0.114	0.109

Variables		Aggression index	
	Duration of snout contact	**0.164**	0.021
Model sow test			
	Latency to snout contact	**-0.269**	0.000
	Bouts of snout contact	0.071	0.323
	Duration of snout contact	0.075	0.295
	Bouts of tactile snout contact	**0.179**	0.012

Examination of the distribution of the data on the variable latency to snout contact in the model sow test indicates that there is an 86% chance that sows that take 2 s or less to make contact with the model sow will be classified as Dominant or Subdominant at Day 2 in Gestation 2.

As shown in Table 4, the latency to snout contact in the model sow test at 24 weeks of age was correlated ($P<0.05$) with the aggression index at Day 2 in Gestation 1 but not ($P>0.05$) Gestation 2.

Table 4 - Spearman correlation coefficients (*r*) between the behavioural variables in the behavioural test at 24 weeks of age and the aggression index at Day 2 of grouping in Gestations 1 and 2 females. (n=200)

Variables		Latency to snout contact in the model sow test at 24 weeks	
Aggression index at Day 2		***r***	**P value**
	Gestation 1	**-0.179**	0.011
	Gestation 2	0.114	0.109

Table 5 - Spearman correlation coefficients (*r*) between the latency to snout contact in the model sow test at 24 weeks of age and immediately prior to grouping in Gestations 1 and 2 (N presented in parantheses).

Variables	Latency to snout contact in the model sow test	
Latency to snout contact in the model sow test at	Gestation 1	Gestation 2
24 weeks	0.094 (n=172, P=0.221)	-0.078 (n=180, P=0.295)
Gestation 1		0.209 (n=125, P=0.019)

As shown in Table 5, the correlations between the latency to snout contact in the model sow test at 24 weeks of age and immediately prior to grouping in Gestations 1 and 2 were low ($P>0.05$) but there was a significant ($P<0.05$) correlation between the latency to snout contact immediately prior to grouping in Gestations 1 and 2.

Experiment 1 - Discussion

The aim of this experiment was to develop predictive tests of 'aggressive motivation' of sows that are related to the aggressive behaviour of the sows when housed in groups. From a preliminary study (Chow, 2010), two potential predictive tests of 'aggressive motivation' were selected and 200 female pigs entering their first and second gestations were used to examine the relationships between the behaviour of the pigs in these two predictive tests and aggression when mixed in groups post-insemination. These two tests basically involved measuring the behavioural response of pigs to both unfamiliar similar-aged gilts or sows and a fibreglass model sow.

Most of the significant relationships were found between the behavioural response of pigs in the two predictive tests immediately prior to grouping in the second gestation and the aggression index at Day 2 of grouping sows in the second gestation. These significant correlations were of a moderate magnitude and indicated that sows that were quicker to interact, and interacted more, with the stimulus in the behavioural tests immediately prior to grouping had higher aggressiveness in groups based on aggression delivered relative to aggression both delivered and received. Furthermore, the magnitude of the relationships found between the behavioural response of pigs in the two tests immediately prior to mixing and the aggression index early after mixing were less in the first than second gestation.

This improvement with age in the magnitude of the relationships between the behavioural response of females in the two tests immediately prior to mixing and aggressive behaviour early after mixing suggest that social experience may be important in the predictive value of these tests. This interpretation is also reflected in the repeatability of the measure the latency to snout contact in the model sow test: while the repeatability of the measure was poor from selection to the first and second parity, the repeatability from the first to second parity was moderate.

In ethological studies, aggression usually refers to behaviour directed towards another individual which could lead to physical injury to the latter and often results in settling status, precedence or access to some object or space between the two (Hinde, 1970). Most intraspecific aggression is highly ritualized and serves to impose social order and territorial limits on the interactions between conspecifics. McFarland (1981) distinguishes, in terms of both function and causation, two main forms of aggression, offensive and defensive aggression. Offensive aggression is elicited to secure or defend some vital resource or place against unwanted intrusion (offensive behaviour) while defensive aggression is used to counter a perceived or actual threat asserted by a rival (defensive behaviour). Furthermore, in the wild fighting might result in dispersion of animals, which is a presumed adaptive function of intraspecific aggression (Wyn-Edwards, 1962) and indeed, Zayan (1990) suggests that the main factor responsible for the intraspecific aggression in pigs is unfamiliarity or 'social strangeness'.

Aggressive behaviour is strongly influenced by experience. In rats and mice, experience of social aggression leading to a victory increases the chances of attacks in subsequent encounters of the same kind (Kudryavtseva et al., 2004). Furthermore, the reward value of intraspecific aggression is indicated in studies in which winning or losing paired encounters can increase or decrease, respectively, subsequent attack rates (see review by Potegal, 1976). It is suggested that the reduction in attack initiation occurring after defeat is likely an avoidance effect due to punishment. Since in many of these paired encounters studies, there was nothing contingent on winning, the increases in attack rate in victorious animals suggest that successful attack may be intrinsically rewarding. Indeed it has been shown in operant conditioning experiments, in which animals perform operant responses to provide themselves with intraspecific attack opportunities, that the animals were actively seeking out targets, rather than fighting to remove the presence of another (see review by Potegal, 1976). It has also been argued that animals in paired encounters learn to avoid pain inflicted by their opponents by attacking them first.

It is widely accepted that like other basic behaviour, aggressive behaviour is strongly influenced by experience and genetics. Consequently, it is perhaps not surprising that rapid and repeated interaction with a strange female pig or a model pig may be correlated with the aggressiveness of female pigs when mixed in groups. However, aggressiveness in groups based on aggression delivered relative to aggression both delivered and received, will be markedly affected by the aggressiveness of others in the group and consequently may partly explain the moderate relationships found in the present study. Nevertheless, these relationships are encouraging, and indeed may be stronger in more experienced sows that recognize their potential fighting ability from a longer history of aggressive interactions with others. Indeed, the relationships between the behavioural response in the two tests and the aggression index at Day 2 of grouping in gilts were less convincing than those for first parity sows, perhaps because these younger pigs were less socially experienced and thus may not have expressed their potential fighting ability in the predictive tests and/or were less effective in predicting fighting ability of others when mixed, exacerbating their aggression in either the predictive tests or the following grouping.

The question of feasibility of selection to improve animal welfare has been under consideration since the 1980s. Aggressive behaviour traits have been found to be heritable in Drosophila melanogaster, mice, adolescent humans and fighting bulls (see Turner et al., 2008). Recent research on groups of 10-13 growing pigs formed from two established groups has shown heritability estimates of 0.26 for receipt of non-reciprocal aggression and 0.38 for reciprocal aggression (Turner et al., 2008). Erhard et al. (1997) suggested that differences between litters in attack latency in a resident-intruder test were sufficiently large to point to possible maternal or genetic effects. Measures for selection obviously must be repeatable and repeatability can be a problem for many behavioural traits (Mills et al. 1997). In the present study, the repeatability of the variable "latency to snout contact" in the model sow test was poor from selection to the first and second parity, but repeatability from the first to second parity was moderate. Thus the 'aggressive motivation' test used in this research may provide a useful measure for selection if animals are scored at least in adulthood after experience of grouping or several times to assess their true phenotype and full- or half-sib analyses were utilised. Obviously discussions with geneticists are required to explore firstly, the potential of this 'aggressive motivation' test relative to other recent and on-going developments in this area and secondly, the need for further development of this 'aggressive motivation' test in a genetic improvement programme.

Furthermore, this predictive tests of aggressive motivation appears to be a useful research tool to study the effects of group composition in terms of homogeneity or heterogeneity of aggressive behaviour in experienced sows. For example, the present findings indicate that there is an 86% chance that sows that take 2 s or less to make contact with the model sow in the predictive test will be classified as Dominant or Subdominant on Day 2 in Gestation 2 (i.e., will deliver aggression at Day 2) and thus only a 14% chance that sows that take 2 s or less to make contact with the fibreglass model pig will deliver aggression at Day 2. This finding indicates that this variable measured prior to grouping is a useful variable in predicting sows that are most likely to display aggression at feeding on the second day of mixing in gestation. Thus, for example, this predictive test could be used to assemble groups of homogenous (generally high or low aggression) and heterogenous (variation) aggressive sows in order to study the effects of aggressive symmetry on individual and group welfare.

Experiment 1 - Conclusion

Therefore, attempting to predict aggressive behaviour in gilts inexperienced with mixing in groups using the present tests is likely to be less successful than for more experienced females because of the role of experience. However, predictive tests measuring the latency and intensity of interaction with a social stimulus may be a useful tool to study the effects of group composition in terms of homogeneity or heterogeneity of aggressive behaviour in experienced sows. Their value as selection tools requires further evaluation.

3. Experiment 2 - The relationship between individual sow aggressiveness and individual welfare

Experiment 2 - Introduction

High levels of aggression are observed when unfamiliar sows are mixed under commercial conditions (see reviews: Arey and Edwards, 1998; Barnett et al., 2001; Spoolder et al., 2011) or when resources such as space (Weng et al., 1998; Hemsworth et al., 2013) or food (Schneider et al., 2007) are restricted. Aggression can compromise sow welfare by increasing the occurrence of injury. In addition, conditions leading to increased aggression (e.g. overcrowding) have been associated with stress, which can negatively impact sow health and productivity. However, individual variations in the behavioural and physiological responses of sows to stress means that the welfare of some group-housed sows may be more compromised than others, an effect that can be overlooked when assessing welfare at a group level. As Australia moves towards group housing of sows, it's important to understand how individuals within the system are affected so that vulnerable sows may be protected.

Intraspecific variation in response to stress has been identified in fish (Silva et al., 2010), geese (Kralj-Fišer et al., 2010), laying hens (Bradshaw, 1992), dairy cows (Mülleder et al., 2003), beech marten (Hansen and Damgaard, 1993) and dogs (Horvath et al., 2007). Animals living in the wild have to overcome numerous challenges, for example climatic change, food shortage and sexual competition. It has been theorised that intraspecific variation ensures different individuals thrive under different environmental conditions thus safeguarding the ongoing survival of the species (Chitty, 1960).

Mice that have been bred from aggressive or non-aggressive lines vary in their aggressive behaviour (Lagerspetz 1961, 1964, 1975; Benus et al., 1990; Koolhaas et al., 1999) and both social and non-social behaviours (Benus et al., 1990) and physiology (Koolhaas et al., 1999). In addition, aggressive mice have been shown to have a lower cortisol response, which indicate reduced hypothalamic-pituitary-adrenal (HPA) sensitivity, but higher heart rate and catecholamine concentrations, which indicate higher sympathetic nervous system (SNS) response, to stress (Koolhaas et al., 1999). They are also rigid in behaviour whereas less aggressive animals show behavioural flexibility (Benus et al., 1990).

Individual variation in the aggressive behaviour of pigs has been well documented (Mount and Seabrook, 1993; Mendl, 1992; Verdon and Hemsworth, 2011; Hansen et al., 1982; Ruis et al., 2002; D'Eath et al., 2009; Turner et al., 2009; Zanella et al., 1998). There may be a relationship between individual sow aggressive behaviour and individual welfare. Zanella et al. (1998) determined that in both stable groups and stalls dominant and subordinate sows showed the lowest levels of diurnal cortisol, while the intermediate sows had the highest. Furthermore, Mendl et al. (1992) observed 37 gilts over a full gestation and lactation period that were repeatedly exposed to high levels of aggression due to dynamic housing conditions. Mendl et al. (1992) were able to classify gilts into three different categories based upon their ability to displace others in agonistic interactions. Using the categories of high (displaced other gilts more often than was displaced), low (displaced more often than displaced other gilts) and no (displaced no other gilts) success gilts, Mendl and colleagues, similar to Zanella et al. (1998), found distinct differences between the categories in regard to behavioural and physiological reactions. Hence, individual variation in the use or avoidance of aggression could be a consequence of alternative strategies that sows adopt in an attempt cope with a stressful environment, and may impact individual welfare and reproduction.

This main objective of this experiment was to determine whether pregnant group-housed sows classified into three distinct categories (submissive, subdominant, dominant) based on individual aggressiveness (aggression delivered and aggression received) differed in individual sow welfare (stress physiology, skin injuries, litter size (born alive and total born) and live weight gain. The main hypothesis being tested was that, in comparison to subdominant and dominant sows, submissive sows have the poorest welfare, defined in terms of aggression received, skin injuries, live weight gain, cortisol and litter size.

Experiment 2 - Material and Methods

Facilities

This experiment was conducted in a gestation unit, specifically renovated for this research, in a large commercial piggery in southern NSW, Australia, and commenced in October 2010 and concluded in February 2012. The experimental building was 61m long and 19m wide, with a galvanized roof and adjustable blinds on the sides. The experimental shed was enclosed by half length walls, meaning that the sows were partially exposed to the environmental conditions. On days when the internal temperature exceeded 26^{o}C sprinklers above each pen were activated for 3 minutes on and 15 minutes off.

Within the unit 16 pens (3.7m x 4.8m) in the boar shed were used for the experiment. Each pen had partially slatted floors with a solid cement lying/feeding are and a slatted dunging area, they were fitted with 2 feed over-header feed droppers and one drink nipple. One video camera (focal range 14m^2) with built-in infra-red (IR) lights were positioned above each pen and recorded for one hour after mixing, and from 0700 to 1700 on Days 2 and 24 post-mixing.

All animal procedures were conducted with prior institutional ethical approval under the requirement of the NSW Prevention of Cruelty to Animals Act 1985 in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organisation/Australian Animal Commission *Australian code of practice for the care and use of animals for scientific purposes*.

Animals and treatments

The animals studied were Large-white x Landrace commercial gilts over 5 replicates (50 gilts per replicate) and two gestations (n=200/gestation). The gilts were housed in groups of 30 (space allowance of 1.4 m^2/gilt) from 22 to 31 weeks of age, when they were then housed in groups of 60 (space allowance of 1.4 m^2/gilt). Gilts detected in oestrus from 32 weeks of age were transferred to stalls for insemination. Gilts were twice artificially inseminated (morning/afternoon insemination routine) and within 7 days of insemination randomly mixed into pens of 10 between 0800 and 1300 h. Prior to mixing symbols were sprayed on the backs of gilts allowing for individual identification. One week prior to farrowing, gilts were moved to farrowing crates where they remained until piglets had been weaned. After piglets were weaned, sows were housed in stalls, twice artificially inseminated (morning/afternoon insemination routine) and within 7 days randomly mixed into groups of 10 (space allowance of 1.8m^2/sow) and allocated to different pens for their second gestation. They remained in these groups for the remainder of the gestation, and the same procedures as for first gestation were applied.

Gilts and sows during gestation were fed a standard commercial gestation pelleted diet (13.1MJ/kg DM, and 12.8% protein; 2.5 Kg/sow/day) delivered onto the floor in four feeding bouts (approximately 07:00, 08:00, 09:00 and 10:00 h) via on over-header hopper. Water was supplied *ad libitum*.

Measurements

Cortisol concentrations

Blood samples were taken on the day after mixing (Day 2) and Days 9 and 51 at approximately 12:00 h by venipuncture of the jugular vein. A 6mL sample was taken in a heparinised tube (BD Vacutainer® BD, Belliver Industrial Estate, Plymouth, UK). For each animal, a maximum of two minutes was allowed to obtain the sample, to avoid an acute stress response associated with handling and blood sampling.

The individual samples were centrifuged at 7000 rpm and the plasma poured off and stored at -20ºC until analysed. Plasma cortisol was measured using a commercial radioimmunoassay kit (Cortisol GammaCoat RIA kit CA-1549, Dia Sorin Inc., Stillwater MN, USA).

Behaviour

Aggressive behaviours are defined in Table 7 and by Samarkone and Gonyou (2009). The number of aggressive acts delivered and received by each individual pig during the observation period was recorded. Fights were classified as aggressive interactions involving the same pair of animals that exceed five seconds, and were recorded as one act of aggression delivered and received for both individuals in the fight and for every 5 seconds lapsed. Only when the full head of the attacking animal and the identifying symbol of the aggression delivering/receiving animal were clearly in the field of view were aggressive interactions recorded.

Aggressive behaviour (aggression delivered and aggression received) of individuals was observed after each of four feed drops on Days 2, 9 and 51 post-mixing using continuous sampling for six successive five-minute time periods (total of 30 minutes) after each of four daily feed drops. From the observations on aggressive behaviour at Day 2, the aggression index for each sow was calculated as the ratio of aggression delivered to the total number of aggressive interactions (i.e., aggression delivered/(aggression delivered + aggression received)). The aggression index at Day 2 was used since aggression between group-housed sows that are restrictively fed is most pronounced early after grouping (Arey and Edwards, 1998; Barnett et al., 2001. Using these data, sows were classified as dominant (D), subdominant (SD) or submissive (SM) (see statistical analysis).

Table 6 - Ethogram of behaviours classified as aggressive behavior

Behaviour	Description
Parallel pressing	Pigs stand side by side and push with shoulders against each other, throwing the head against the neck or head of the other

Behaviour	Description
Inverse parallel pressing	Pigs face front to front and then push their shoulders against each other, throwing the head against the neck and flanks of the other.
Head to body knocking	A rapid thrust upwards or sideways with the head or snout against any part of the body behind the ears. Most of the knocks are performed against the front half of the receiver. The performers mouth is shut.
Head to head knocking	A rapid thrust upwards or sideways with the head or snout against the neck, head or ears of the receiver. The performer's mouth is shut.
Bite	A pig delivers a knock with the head against the head, neck or body of the other pig with the mouth open
Fights	One or a combination of above aggressive behaviours that exceeds 5 seconds.

Skin Injuries

The same assessment described by Karlen et al. (2007) was used to describe skin injuries for individual sows. Skin injuries were categorized into fresh injuries (scratches, abrasions, cuts, and abscesses), or partially healed or old injuries. Each side of the sow's body was divided into 21 areas as shown in Fig. 2 and described as follows: face (1), ear (2), neck (3), throat (4), processi scapulae (5), elbow (6), carpus (7), fetlock (8), coronary edge of the foreleg (9), hoof of the foreleg (10), sole of the foreleg (11), accessory digits of the foreleg (12), back and flank (13), tail and vulva (14), stifle (15)m hock (16), coronary edge of the back leg (17), hoof of the back leg (18), sole of the back leg (19), accessory digits of the back leg (20), and udder (21). The number and type of skin injuries were recorded on Days 2 and 24 post-mixing.

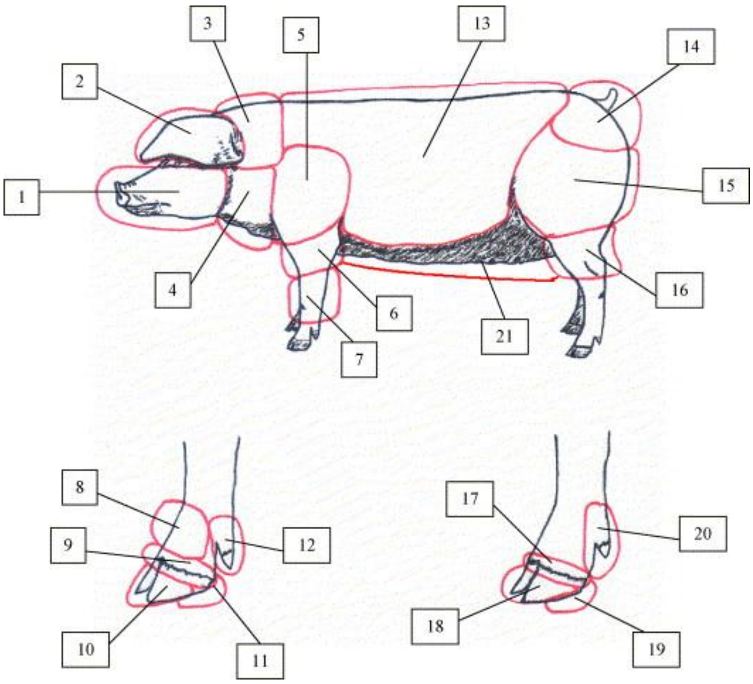

Figure 2 - Divisions of the surface of the sow where injures will be assessed (Karlen et al., 2007)

Productivity and other measures

Live weight gain

Sows were weighed on Day 2 and Day 100. From this a live weight gain for the gestation was calculated.

Reproductive Performance

All sows farrowed in a common farrowing environment. The reproductive performance data collected allowed for the litter size (born alive and total born) to be calculated.

Statistical Analysis

Because of removals of unproductive animals and to ensure each gestation had 200 animals at mixing, a total of 275 animals were used in this experiment. Thirty-seven females were removed from treatment in Gestation 1 and 33 from Gestation 2 for either reproductive or non-reproductive reasons. Thus some animals were observed in the first gestation and not the second, and vice versa, but there were 126 animals common to both gestations.

Due to a technical malfunction, there were no Day 51 behavioural data for replicate 4 in the first gestation. One sow in the second gestation escaped the pen before any data could be obtained. Hence Gestation 2 has only 199 data points on Day 2.

The aggression index for sows, calculated as the ratio of aggression delivered to the total number of aggressive interactions, varied from between 0 and 1. Female pigs were classified as 'Dominant' if they delivered more aggression than they received on Day 2 (aggression index > 0.5), 'Subdominant' if they received more aggression than they delivered (aggression index >0, <0.5) and 'Submissive' if they delivered no aggression (aggression index=0). This classification is similar to that devised by Mendl et al. (1992), and used later by Zanella et al. (1998), but groups of researchers used displacements rather than aggression. Due to the difficulties in recognising all agonistic interactions and the expected high levels of aggression at Day 2, this experiment found it suitable to use aggression rather than displacements in calculating this classification. Mendl et al. (1992) argued that the method of using displacements is preferable to calculating the dominance hierarchy using the multitude of interactions between individuals due to the high number of reversals in hierarchical positions often observed within dyads. In addition, a classification approach is useful because the relationship between social status and welfare may not be linear, although examination of the partial correlation analysis will test this assumption.

Part 1: Repeatability of aggression

Many variables, including the sow aggression index, did not conform to a normal distribution as indicated by visual methods (Q-Q plots, SPSS, 2011). Spearman rank order correlation coefficients (SPSS statistical package, SPSS 17.0, SPSS Inc., Chicago, Illinois, USA) were, therefore, used to test for repeatability of sow aggression index both within and between gestations.

Part 2: Aggression and welfare

Data were transformed appropriately when the assumption of normality was not fulfilled and statistical outliers removed for the following variables; live weight gain and plasma cortisol. Data that were greater than the 75th percentile plus 1.5 x the interquartile range (IQR), or less than the 25th percentile minus 1.5 x ICR were removed as statistical outliers. Data were analyzed two ways. The first was using partial correlations and controlling for gestation. This analysis was conducted on the 126 female pigs common to both gestations. The second method involved classifying animals as Dominant, Subdominant and Submissive (described above) before applying an univariate ANOVA(SPSS statistical package, SPSS 17.0, SPSS Inc., Chicago, Illinois, USA) to compare the behaviour, physiology and reproduction of the three classifications of females in each gestation. This method used all females and classification was the between-subjects factor and pen was controlled for as a random factor. Multiple comparisons between means were performed using the LSD test.

Experiment 2 - Results

Part 1: Repeatability of aggression

The aggression index calculated on the day after mixing (Day 2) in Gestation 1 was highly and positively correlated with the index calculated for Day 9 (r=0.694, N=197, P<0.001) and moderately correlated with the index calculated for Day 51 (r=0.533, N=137, P<0.001). The correlations between the aggression index on Day 2 and that on Day 9 (r=0.741, N=196, P<0.001) and Day 51 (r=0.720, N=177, P<0.001) were stronger in the second gestation. Similarly, aggression index on Day 2 in Gestation 1 was positively correlated with that on Day 2 in Gestation 2, although this correlation was weaker than the within-gestation relationships (r=0.500, N=125, P<0.001).

Part 2: Aggression and welfare

Aggressive behaviour

To investigate the relationships between aggression and welfare, the female animals were classified into three groups according to their relative aggressiveness on Day 2. In both gestations, the majority of animals were classified as Subdominant (received more aggression than they delivered; Gestation 1: 45.5%, Gestation 2: 44.2%). Animals that delivered more aggression than they received were the next prominent (Dominant; Gestation 1: 35.5%, Gestation 2: 33.2%), with animals that delivered no aggression the least common (Submissive; Gestation 1: 19%, Gestation 2: 22.6%).

As shown in Table 7, the three classifications of female pigs (i.e., Dominant, Subdominant and Submissive), differed significantly in aggression delivered on Day 2 (Gestation 1 P=0.00; Gestation 2 P=0.00), Day 9 (Gestation 1 P=0.00; Gestation 2 P=0.00) and Day 51 (Gestation 1 P=0.00; Gestation 2 P=0.00), with dominant females consistently delivering the most aggression and submissive females the least.

In addition to delivering the most aggression, dominant sows received the least aggression on Day 2 (Gestation 1 P=0.002; Gestation 2 P=0.00), Day 9 (Gestation 1 P=0.00; Gestation 2 P=0.00) and Day 51 (Gestation 1 P=0.00; Gestation 2 P=0.00). This is with the exception of Gestation 1, Day 2, in which dominant animals received the same amount of aggression as submissive animals (P=0.476). Aggression received by submissive and subdominant animals did not differ in either Gestation 1 (Day 2 P=0.305; Day 9 P=0.704; Day 51 P=0.528) or Gestation 2 (Day 2 P=0.656; Day 51 P=0.786), with the exclusion of Day 9 in Gestation 2 (P>0.05).

Table 7 - Gestations 1 and 2 relationships between submissive (SM), subdominant (SD) and dominant (D) classifications and aggressive behaviour. Means (with back transformed means in parentheses) and standard errors (for transformed data in parantheses and in italics) are presented.

Variable	Aggression classification				P value
	SM	SD	D		
Gestation 1					
*Aggression Delivered**					
Day 2	1.03 (0.08)[a] *(0.018)*	2.61 (7.15)[b] *(0.121)*	6.30 (42.4)[c] *(0.229)*	$F_{2,197}$=181	**0.000**
Day 9	1.55 (1.97)[a] *(0.129)*	2.98 (11.0)[b] *(0.186)*	5.24 (33.4)[c] *(0.315)*	$F_{2,194}$=70.1	**0.000**
Day 51	1.90 (3.83)[a] *(0.232)*	2.49 (6.83)[b] *(0.163)*	3.50 (14.5)[c] *(0.257)*	$F_{2,134}$=11.1	**0.000**
*Aggression Received**					
Day 2	4.03 (16.5)[ab] *(0.184)*	4.27 (18.2)[a] *(0.106)*	3.72 (15.7)[b] *(0.200)*	$F_{2,197}$=7.15	**0.002**
Day 9	4.23 (18.3)[a] *(0.203)*	4.33 (19.0)[a] *(0.118)*	*3.51 (13.4)[b]* *(0.175)*	$F_{2,194}$=16.2	**0.000**
Day 51	3.34 (11.0)[a] *(0.190)*	3.19 (10.3)[a] *(0.138)*	*2.42 (6.2)[b]* *(0.166)*	$F_{2,134}$=9.92	**0.000**
Gestation 2					
*Aggression Delivered**					
Day 2	1.06 (0.16)[a] *(0.022)*	2.54 (6.31)[b] *(0.097)*	5.56 (33.7)[c] *(0.240)*	$F_{2,196}$=142	**0.000**
Day 9	1.95 (3.93)[a] *(0.162)*	2.59 (8.23)[b] *(0.172)*	5.59 (36.1)[c] *(0.302)*	$F_{2,193}$=68.5	**0.000**
Day 51	1.61 (2.19)[a] *(0.130)*	2.23 (5.4)[b] *(0.134)*	4.35 (20.6)[c] *(0.216)*	$F_{2,174}$=62.0	**0.000**
*Aggression Received**					
Day 2	4.02 (16.7)[a] *(0.186)*	4.11 (16.9)[a] *(0.105)*	2.77 (7.95)[b] *(0.139)*	$F_{2,196}$=42.9	**0.000**
Day 9	4.55 (21.4)[a] *(0.201)*	4.11 (17.4)[b] *(0.131)*	2.92 (9.06)[c] *(0.156)*	$F_{2,193}$=27.9	**0.000**
Day 51	3.36 (11.9)[a] *(0.213)*	3.30 (11.0)[a] *(0.118)*	2.34 (5.69)[b] *(0.144)*	$F_{2,174}$=15.8	**0.000**

*Aggression delivered and received were square root(X+1) transformed prior to statistical analysis.
Within rows, significant differences are indicated by different superscripts; [a,b,c] P<0.05

Skin Injuries

Partial correlations, controlling for gestation, between the aggression index on Day 2 and welfare variables are presented in Table 8. There were parallels between relationships using aggression delivered/received and the aggression index. However, the strength of the relationships was best when using the aggression index, and hence only those relationships are reported. Aggression index was not related to either total (r=0.067, N=126, P=0.306) or fresh (r=0.042, N=126, P=0.527) injuries on Day 2. However, the aggression index and injuries were significantly and negatively correlated on both Day 9 (total injuries r=-0.280, N=126, P<0.001; fresh injuries r=-0.244, N=126, P<0.001) and Day 51 (total injuries r=-0.472, N=126, P<0.001; fresh injuries r=-0.274, N=126, P<0.001). The relationships on Day 51 were stronger than those on Day 9.

As shown in Table 9, there were no differences in fresh injuries between dominant, subdominant or submissive classifications on Day 2 for either the first (P=0.064) or second (P=0.478) gestations. Similarly, there was no differences between the aggression classifications in total injuries on Day 2 in Gestation 1 (P=0.342)or Day 2 in Gestation 2 (P=0.340).

By Day 9 dominant animals had sustained the least injuries as indicated by total injuries scores in both Gestation 1 (P=0.002) and Gestation 2 (P=0.000). Similarly, dominant sows had the fewest fresh injuries on Day 9 in both Gestation 1 (P=0.024) and Gestation 2 (P=0.000).

Dominant animals continued to have the least total injuries on Day 51 of both Gestation 1 (P=0.000) and Gestation 2 (P=0.000). However while subdominant and submissive females had the same total injuries on Day 51 of Gestation 1 (P=0.260), submissive females had the most total injuries in Gestation 2 (P=0.001). Interestingly, although submissive and subdominant female pigs received the same amount of aggression (Table 7), submissive female pigs had the most fresh injuries on Day 51 in both Gestations 1 (P=0.00) and 2 (P=0.000).

Table 8 - Partial correlations, controlling for gestation, between aggression index on day 2 and welfare variables.

Variables	**Day 2 Aggression index**	
	r	**P-value**
*Fresh Injuries**		
Day 2	0.042	0.527
Day 9	-0.244	**0.000**
Day 51	-0.274	**0.000**
*Total Injuries**		
Day 2	0.067	0.306
Day 9	-0.280	**0.000**
Day 51	-0.472	**0.000**
*Cortisol***		
Day 2	-0.069	0.291
Day 9	-0.066	0.319
Day 51	-0.056	0.392
Live Weight Gain	0.149	**0.035**
Litter size (Born Alive)	0.148	**0.036**

*Injuries (total and fresh) were square root(X+1) transformed prior to statistical analysis.
**Cortisol data were $log_{10}(X+1)$ transformed prior to statistical analysis

Table 9 - Gestations 1 and 2 relationships between submissive (SM), subdominant (SD) and dominant (D) classifications and skin injuries (total and fresh). Means (with back transformed means in parentheses) and standard errors (for transformed data in parentheses and in italics) are presented

Variable	Aggression classification			F	P value
	SM	SD	D		
Gestation 1					
*Fresh Injuries**					
Day 2	4.87 (27.6) *(0.360)*	5.00 (27.1) *(0.184)*	4.48 (23.3) *(0.244)*	$F_{2,197}$=2.94	0.064
Day 9	2.77 (8.26) *(0.212)*	2.87 (8.19) *(0.100)*	2.54 (6.46) *(0.119)*	$F_{2,194}$=4.10	0.024
Day 51	2.63 (6.84)[a] *(0.171)*	2.05 (3.73)[b] *(0.080)*	1.90 (3.35)[b] *(0.108)*	$F_{2,179}$=8.69	**0.001**
*Total Injuries**					
Day 2	5.69 (35.4) *(0.330)*	5.75 (35.0) *(0.178)*	5.41 (32.0) *(0.230)*	$F_{2,197}$=1.10	0.342
Day 9	5.61 (33.4)[a] *(0.289)*	5.63 (33.0)[a] *(0.158)*	4.81 (24.6)[b] *(0.186)*	$F_{2,194}$=7.20	**0.002**
Day 51	5.*19 (28.8)*[a] *(0.298)*	*4.78 (25.5)*[a] *(0.207)*	*3.77 (17.0)*[b] *(0.242)*	$F_{2,179}$=15.9	**0.000**
Gestation 2					
*Fresh Injuries**					
Day 2	4.77 (24.2) *(0.234)*	4.96 (26.1) *(0.167)*	5.40 (32.4) *(0.254)*	$F_{2,196}$=0.749	0.478
Day 9	2.98 (9.66)[a] *(0.203)*	2.60 (6.76)[a] *(0.107)*	1.98 (3.43)[b] *(0.088)*	$F_{2,193}$=9.40	**0.000**
Day 51	3.07 (10.1)[a] *(0.214)*	2.45 (5.98)[b] *(0.111)*	2.30 (5.07)[b] *(0.114)*	$F_{2,174}$=7.92	**0.001**
*Total Injuries**					
Day 2	5.25 (29.1) *(0.238)*	5.48 (31.8) *(0.175)*	5.97 (39.1) *(0.258)*	$F_{2,196}$=1.11	0.340
Day 9	7.62 (63.6)[a] *(0.390)*	7.16 (54.2)[a] *(0.215)*	5.82 (37.1)[b] *(0.259)*	$F_{2,193}$=9.42	**0.000**
Day 51	7.91 (66.2)[a] *(0.364)*	6.60 (48.1)[b] *(0.263)*	4.56 (23.0)[c] *(0.237)*	$F_{2,174}$=35.5	**0.000**

*Fresh and total injuries were square root transformed prior to statistical analysis.
Within rows, significant differences are indicated by different superscripts; [a,b,c] $P<0.05$

Stress physiology

Partial correlations, controlling for gestation, revealed no relationships between aggression index and cortisol on Day 2 (r=-0.069, N=126, P=0.291), Day 9 (r=-0.066, N=126, P=0.319) or Day 51 (r=-0.056, N=126, P=0.392).

The relationships between aggression classification and cortisol concentrations are shown in Table 10. When analyzed this way, cortisol did not differ between Submissive, Subdominant and Dominant classifications on Day 2 (P=0.200), Day 9

(P=0.155)or Day 51 (P=0.193) of Gestation 1. In Gestation 2, however, dominant females had lower cortisol concentrations on Day 2 than subdominant females (P=0.004) but not submissive females (P=0.470). However, these relationships were not seen on either days 9 (P=0.468) or 51 (P=0.768).

Table 10. Gestations 1 and 2 relationships between submissive (SM), subdominant (SD) and dominant (D) classifications and plasma cortisol concentrations. Means (with back transformed means in parentheses) and standard errors (for transformed data in parentheses and in italics) are presented.

Variable	Aggression classification			F	P value
	SM	SD	D		
Gestation 1					
*Cortisol**					
Day 2	1.17 (19.9) *(0.049)*	1.13 (17.1) *(0.028)*	1.21 (19.3) *(0.035)*	$F_{2,188}$=1.67	0.200
Day 9	1.25 (19.4) *(0.047)*	1.18 (18.6) *(0.029)*	1.12 (15.9) *(0.033)*	$F_{2,189}$=1.95	0.155
Day 51	1.26 (21.6) *(0.057)*	1.25 (21.6) *(0.031)*	1.24 (19.9) *(0.032)*	$F_{2,176}$=1.71	0.193
Gestation 2					
*Cortisol**					
Day 2	1.10 (18.2)^{ab} *(0.045)*	1.20 (20.2)^{a} *(0.034)*	1.05 (14.6)^{b} *(0.041)*	$F_{2,195}$=5.08	**0.010**
Day 9	1.12 (15.2) *(0.033)*	1.13 (16.4) *(0.029)*	1.15 (16.7) *(0.088)*	$F_{2,193}$=0.772	0.468
Day 51	1.27 (21.9) *(0.039)*	1.24 (20.1) *(0.027)*	1.29 (22.1) *(0.028)*	$F_{2,174}$=0.266	0.768

*Cortisol concentrations were $\log_{10}(X+1)$ transformed prior to statistical analysis.
Within rows, significant differences are indicated by different superscripts; ^{a,b,c} P<0.05

Live weight gain

Partial correlations, controlling for gestation, revealed that aggression index on Day 2 was significantly and positively correlated with live weight gain (r=0.149, N=126, P=0.036; Table 2). Furthermore, as shown in Table 5, dominant animals gained the most weight in Gestation 1 (P=0.00) and Gestation 2 (P=0.009).

Reproduction

There was a significant, positive correlation, controlling for gestation, between the aggression index on Day 2 and the number of piglets born alive (r=0.148, N=126, P=0.036) (Table 8). However, as shown in Table 11, females of different classifications did not differ in the number of piglets born (either total or alive) in Gestation 1 (born alive, P=0.846; total born, P=0.818) and Gestation 2 (born alive, P=0.467; total born, P=0.327).

Table 11 - Gestations 1 and 2 relationships between submissive (SM), subdominant (SD) and dominant (D) classifications, live weight gain and reproduction. Means and standard errors (in parantheses) are presented.

Variable	Aggression classification			F	P value
	SM	SD	D		
Gestation 1					
Live weight gain	69.5[ab] *(2.1)*	66.9[a] *(1.5)*	73.9[b] *(1.5)*	$F_{2,136}$=12.8	**0.00**
Litter-size					
Total	9.8 *(0.43)*	10.5 *(0.27)*	10.8 *(0.34)*	$F_{2,156}$=0.202	0.818
Born Alive	9.7 *(0.52)*	10.1 *(0.28)*	10.3 *(0.36)*	$F_{2,158}$=0.167	0.846
Gestation 2					
Live weight gain	67.4[ab] *(1.9)*	63.6[a] *(1.7)*	71.1[b] *(1.9)*	$F_{2,121}$=5.22	**0.009**
Litter-size					
Total	11.0 *(0.44)*	11.0 *(0.31)*	11.9 *(0.35)*	$F_{2,163}$=1.15	0.327
Born Alive	10.6 *(0.44)*	10.6 *(0.31)*	11.4 *(0.34)*	$F_{2,163}$=0.774	0.467

Within rows, significant differences are indicated by different superscripts; [a,b,c] P<0.05

Discussion

Part 1:Repeatability of aggression

Significant relationships were found in the present study between the aggression index on Day 2 with aggression index on Day 9 and Day 51 in both gestations, although the relationships were stronger in the second gestation than the first. In addition, the aggression index on Day 2 of Gestation 1 was moderately but significantly correlated with that on Day 2 in Gestation 2, although this correlation was weaker than within gestation relationships. Aggressiveness in young pigs has been shown to be a moderately heritable trait (Turner et al., 2008, 2009; D'Eath et al., 2009) and DNA markers have been identified in two genes that also have multiple and consistent associations with stress responsiveness and aggressive behaviour (Muráni et al., 2010). However, the correlations for aggression index were stronger within gestations in the present study than they were between. Individual aggressive behaviour may be related to the behaviour of other animals in the group. Indeed in young pigs, the intensity and duration of fighting after mixing as well as the number of injuries has been related to the composition of the group in terms of individual aggression (Erhard et al., 1997; Ruis et al., 2002; Hayne & Gonyou, 2006; D'Eath et al, 2009). Additionally, experience can affect subsequent aggressive behaviour. In mice Kudrvavtseva et al. (2004) showed that animals that lose an aggressive interaction are less likely to engage in ensuing aggression of a similar nature. Gilts are socially inexperienced and thus may be less effective at predicting the fighting ability of others and consequently aggression may be exacerbated in groups of mated gilts. Following experience of group-housing in the first gestation, low-ranking pigs may have learnt to avoid high-ranking pigs, while the latter pigs may be more confident of their fighting ability and respond accordingly, and consequently aggression in the groups of second gestation sows may be less. This raises questions on the suitability of gilts as a model for the behaviour of the sow.

Part 2: Aggression and welfare

Aggressive behaviour

Using the aggression index to classify animals as Submissive, Subdominant and Dominant results in a similar distribution of animals in each category as that reported by Mendl et al. (1992), who used displacements rather than aggression to classify animals. The majority of animals in the present study were classified as Subdominant, or middle ranking, with fewer proportions of Dominant and Submissive. Dominant animals delivered the most aggression on Day 2. This is in agreement with the findings by Meese and Ewbank (1973) who observed the aggressive behaviour of young pigs in groups of eight and found that the peak in aggression after mixing was almost entirely attributed to the animal that later became Dominant. Similarly, Krauss and Hoy (2011) found that when unfamiliar sows were mixed 61% of fights involved the sow that became the most Dominant.

Aggression after mixing is reported to reach baseline levels within 1-2 days (Marchant-Forde, 2010) with no further reductions from days 2 to 4 post-mixing (Krauss and Hoy, 2011). Dominant females in the present study continued to deliver the most aggression on Day 9 and Day 51 after mixing. Sows can minimize the need to use aggression through the regulation of a stable dominance hierarchy using what is known as an 'avoidance order', which is characterised by low-ranking sows actively avoiding conflict with those higher ranking (Jensen, 1982). When space is limited low-ranking sows are less able to avoid interaction with those more dominant. In addition, sows are fed a restricted diet so competition for access to feed in substantial. As a result Dominant sows may continue to deliver aggression as they protect food as a valuable resource.

If a female is successful in becoming Dominant after engaging in fights at mixing her chances of receiving further aggression are reduced. Dominant females received the least aggression throughout both gestations. However, this was not the case on Day 2 in Gestation 1, where there was no difference in the amount aggression received by Dominants and Submissive females. This apparent anomaly may be due to the first parity females being less socially experience than second-parity females. Furthermore Subdominant females received more aggression than Dominants on Day 2 of the first gestation, even though Submissive females did not. Mendl et al. (1992) hypothesised that the difference between low success (were displaced more than they displaced others) and no success (displaced no-one) gilts is that low success gilts remain aggressive and competitive despite defeat, while no success gilts avoid competition thus reducing their involvement in aggression. Thus, due to the persistence of the middle ranking animals to continue with using aggression despite their lack of success, they experience more attacks and aggression from other females.

While Mendl et al. (1992) found that no success animals received less aggression than low success, we found no differences between the two classifications (with the exclusion of Gestation 1 Day 2, (discussed above). The study by Mendl et al. used only 37 gilts that were mixed 7 weeks post-insemination into a dynamic group with considerable space (minimum of 2.5 m^2/gilt) and an electronic sow feeder. In comparison, the present study used 200 animals that were housed in small, stable groups with less space (1.8 m^2/female) and feed was delivered to the floor via two over-head feed droppers. As a result, it may have been more difficult for submissive sows to avoid aggression in the present study, particularly when feeding.

Skin Injuries

The frequency of skin injuries is commonly used as an animal-based indicator of reduced welfare (Barnett and Hemsworth, 2009). In groups of growing pigs the total numbers of injuries 24-hours after mixing are related to the amount of time a pig spent in reciprocal and non-reciprocal aggression (Turner et al., 2006). Thus pigs that avoid aggression after mixing could be identified by their low levels of injuries. In a later study, Turner et al. (2009) found lesion frequency in finishing pigs was positively correlated at 24 hours post-mixing and 3 weeks later, indicating that post-mixing injuries are predictive of those sustained under more stable conditions. In this study no relationships were found between aggression index on Day 2 and injuries (fresh and total), nor were there differences in the number of total or fresh injuries sustained by Dominant, Subdominant or Submissive sows on the day after mixing.

Although the aggression index at Day 2 was not correlated with injuries on Day 2 in the present study, the aggression index at Day 2 was negatively correlated with injuries on Days 9 and 51. When pigs are mixed, aggressive animals fight for dominance while delivering more aggression to those who are lower ranking or become lower ranking. Thus while dominant and lower ranking animals may receive aggression early after mixing, animals that are successful in gaining dominance are likely to receive less aggression in the future and have less injuries. Previous studies have also found that dominant sows have a high number of injuries after mixing but reduced injuries in the long term (O'Connell et al., 2003; Arey, 1999).

Dominant sows sustained the least fresh and total injuries on day 9 of both Gestations 1 and 2. Furthermore, partial correlations controlling for gestation indicated negative relations between the aggression index and both fresh and total injuries at Day 9. Skin injuries are commonly used as a proxy measurement for aggression because they are considered to be visual evidence that an animal has received aggression (Schenider et al., 2007; D'Eath et al., 2010; Turner et al., 2006a, 2006b, 2008; Chapinal et al., 2010; Spoolder et al., 2009; Stukenborg et al., 2011), although in large groups injuries may also occur with collisions with pen walls and fittings (Karlen et al., 2007; Hemsworth et al., 2013).

Stress Physiology

There were no differences between aggressive classification and cortisol on day 2, 9 or 51 of the first gestation. This contrasts with the finding of Mendl et al. (1992) in which middle ranking gilts were the most stressed based on basal concentrations of salivary cortisol and the highest peak cortisol response to an adrenocorticotrophic hormone challenge test. However, in agreement with Mendl et al. (1992) in the second gestation in the present study Subdominant sows had the higher plasma cortisol concentrations on Day 2. One of the benefits of gaining dominance is also gaining priority access to resources and reducing the amount of aggression received. On the other hand, experiencing repeated defeat has been shown to result in chronic activation of the HPA axis (Fano, 2001). Mendl et al. (1992) concluded that the experience of attack and defeat by middle ranking animals, which results from their persistent use of aggression despite relative lack of success, was more stressful than the consequences of the behavioural strategies employed by the high ranking and low ranking groups. Furthermore, following the experience of the first gestation, Subdominant sow may be anticipating continual failure.

The partial correlation analysis found no relationships between aggression index and cortisol concentrations. As discussed above, there is evidence from the study by Mendl et al. (1992) on gilts and the results of the present study in the second gestation that Subdominant animals experienced greater stress. Thus the relationship between aggression index and cortisol may not be linear.

Live Weight Gain

Live weight gain was positively correlated with aggression index, and in both gestations dominant pigs gained more weight than either subdominant or submissive pigs. While dominant pigs gain priority access to food, submissive animals who avoid aggression may be sacrificing the opportunity to feed for safety (Verdon et al., 2011). On the other hand, subdominant animals may risk receiving aggression in order to gain some level of intake, but the associated energy expenditure from consistently engaging in aggression could result in reduced weight gain. Interestingly, similar results were reported by Mendl et al. (1992) even though animals were fed using an electronic sow feeder. The authors suggested that increased fear and anxiety of attack could increase basal metabolic rates and thus energy expenditure, compromising growth.

Reproduction

Prolonged stress and sustained elevation of cortisol can disrupt reproductive processes in female pigs, although a proportion of female pigs appear to be resistant to the effects of prolonged stress or sustained elevation of cortisol (Turner et al., 2005). Under conditions of elevated stress, cortisol can permeate the uterine lumen of pregnant sows and inhibit the embryo's ability to attach to the uterine wall (Tsuma et al., 1996) resulting in stillborn births and miscarriages. Mendl et al. (1992) found that middle ranking sows, that had the highest basal cortisol levels, produced piglets of reduced weight in comparison to both the high and low ranked animals. The present study found over the two lactations that the aggression index was positively correlated with the number of piglets born alive. However, no differences were found between aggression classifications and litter size in the present study. Because data from both gestations were utilized in the partial correlation analysis to examine the relationship between aggression and litter size, real effects may have been easier to detect with this analysis than with the analysis of variance conducted on the two gestations separately, particularly for a variable such as litter size in which there is considerable variation

Conclusion

The present study indicates that individual females vary consistently in their aggressive behavioural characteristics during gestation. After mixing, aggressive females risk injury by engaging in fights as they attempt to gain dominance. Additionally, when space is limited, it is more difficult for Submissive females to avoid the more Dominant females so most animals in a group receive injuries early after grouping. While there are some minor differences between the present study and that by Mend et al. (1992), the two studies indicate that once a dominance hierarchy is established, Dominant females have a reduced risk of receiving aggression, and hence reduced injuries. They are also more likely to gain greater weight and experience less stress. In the present study, both increased feed intake through priority access and less stress may have contributed to increased weight gain. While Subdominant and Submissive animals are comparable in terms of aggression received, live weight gain and reproduction, Subdominant females are more likely to experience greater stress but Submissive females have more injuries later in gestation. While Mendl and colleagues (1992) concluded that "the strategy used to cope with the social environment may be as important as the success achieved in agonistic interactions, at least in terms of consequences for physiology and reproduction", the present results indicate that although the most aggressive and Dominant females receive injuries early after grouping, in the long term they have priority of access to feed, have less injuries, lower stress, higher growth rates and are more likely to have higher litter sizes (alive). While Subdominant females are likely to persist longer in displaying aggression to achieve a higher dominance order, Submissive females in groups are likely to benefit from the provision of increased resources such as access to feed, lying space and access to drinkers.

4. Experiment 3 - The effect of group composition on both group and individual sow welfare.

Introduction

Similar to what has been found in many other species, individual pigs vary in aggressive behavior, and these variations may be related to an individual's welfare (Morméde et al., 2002; Mendl et al., 1992; Verdon and Hemsworth, 2011). Verdon et al. (2012) assigned pregnant sows an "aggressive index" (that is, the ratio of aggression delivered to the total number of aggressive interactions) and found that sows displaying low aggressiveness early after mixing had more injuries later in gestation and gained less weight. The authors concluded that less aggressive sows may be at risk of reduced welfare, due to injuries and reduced feed intake.

As shown in the previous experiment in this report, individual aggressiveness, as indicated by an aggression index, was consistent through gestation, and Turner et al. (2006) found reciprocal fighting to be highly heritable in growing pigs. Thus sow aggressiveness may be, at least in part, attributed to an individual's genetics, perhaps providing the opportunity to genetically select against aggressiveness.

However, it was apparent in studying the repeatability of individual aggressiveness in groups in this second experiment in this report that the inter-gestation correlations of aggressiveness were less than the intra-gestation correlations, suggesting changes in aggressive behaviour depending perhaps on experience and group composition. Thus while genetics may in part determine sow aggressiveness, group composition may also contribute.

Furthermore, while selection against aggressiveness may reduce group aggression, aggression nevertheless may play an important role in stabilizing the social structure of the group. When immature pigs were classified on the basis of either slow, medium or fast approach to an unfamiliar human (human approach test: Hayne and Gonyou, 2006) and aggressive or non-aggressive using the latency attack to a smaller intruder (resident-intruder test: Ruis et al., 2002; Erhard et al., 1997) or skin lesion scores (D'Eath et al., 2010), welfare-measured in terms of weight gain, aggression, skin injuries, and plasma cortisol-was improved when pigs were housed in groups of mixed classification in comparison to uniform groups. This present experiment examined whether, in terms of aggressive behavior, heterogeneous groups of sows show less overall aggression than homogeneous groups. The effects on cortisol concentration, injuries and reproductive performance were also examined.

The model pig predictive test for aggression studied in the first experiment of this project was used to identify pigs that were most likely to show aggression early after grouping and those that were most unlikely. The results of the first experiment in this project indicated that there is an 86% chance that sows that take 2 s or less to make contact with the model sow in the predictive test will be classified as Dominant or Subdominant on Day 2 in Gestation 2 (i.e., will deliver aggression at Day 2) and thus only a 14% chance that sows that take 2 s or less to make contact with the fibreglass model pig will deliver aggression at Day 2. Used with caution, this predictive test may be useful in providing an insight into the impact of group composition on aggression and welfare of group-housed sows. Thus this predictive test was used to assemble groups of either sows predicted to be Dominant and Subdominant or of sows randomly mixed.

Material and Methods

Facilities

This experiment was conducted in a gestation unit, specifically renovated for this research, in a large commercial piggery in southern NSW, Australia,. The experimental building was 61 m long and 19 m wide, with a galvanized roof and adjustable blinds on the sides. The experimental shed was enclosed by half length walls, meaning that the sows were partially exposed to the environmental conditions. On days when the internal temperature exceeded 26°C sprinklers above each pen were activated for 3 min on and 15 min off.

Within the unit 12 pens (3.7 m x 4.8 m) in the boar shed were used for the experiment. Each pen had partially slatted floors with a solid cement lying/feeding are and a slatted dunging area, they were fitted with 2 feed over-header feed droppers and one drink nipple. One video camera (focal range 14m^2) with built-in infra-red (IR) lights were positioned above each pen and recorded for one hour after mixing, and from 07:00 to 17:00 h on the second day of mixing (labeled Day 2) and Day 24.

All animal procedures were conducted with prior institutional ethical approval under the requirement of the NSW Prevention of Cruelty to Animals Act 1985 in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organisation/Australian Animal Commission *Australian code of practice for the care and use of animals for scientific purposes*.

Animals and Treatments

Large-white x Landrace commercial sows (parity 1-6, n=360) over 6 replicates (60 sows per replicate, split over two weeks) were mixed into pens (3.7m x 4.8m) of either homogeneous aggressive classified or random heterogeneous groups of 10 sows (1.8m^2/sow) within 2-3 days of insemination. Sows were individually marked for identification and mixed into treatment pens between 1200 and 1400 h. The experiment commenced in June 2012 and concluded in October 2012.

For selection, sows were randomly moved from their home mating stalls into a specifically designed tests stall (Fig.3) in the gestation facility. Previous experiments (see Experiment 1) have shown that the latency to contact a “model test” pig is negatively correlated with the aggressive behaviour of a sow on the day after mixing. To maintain consistency with the test procedures in the present experiment with that in Experiment 1, testing consisted first of introducing test sows to an unfamiliar sow in an adjacent stall (see Fig. 1) for 30 s, even though no measures were recorded. Sows were then moved forward into a stall next to a fibre-glass “model test” sow and observed for 5 s, in which time the latency for the sow’s snout to cross the barrier between the stalls was recorded. Sows that made contact in 2 s or less were considered as “aggressive”. After testing sows were moved back to their stalls.

Once 10 aggressive sows had been identified for the homogenous aggressive pens (20 every second week), 20 additional sows (10 every second week) were randomly selected and stall-tested. These additional sows formed the random heterogeneous treatment pens. Following testing, sows were mixed into their allocated pens (aggressive sows or randomly selected).

The sows remained in these groups for the remainder of the gestation. After pregnancy was confirmed at 28 days post-mixing, sows were moved out of experimental pens and, without re-mixing, into pens with partial feeding stalls for the remainder of the gestation. One week prior to farrowing, sows were then moved to farrowing crates where they remained until piglets had been weaned.

Animals were fed a standard commercial gestation pelleted diet (13.1MJ/kg DM, and 12.8% protein; 2.5 Kg/sow/day) delivered onto the floor in four feeding bouts (approximately 0700, 0800, 0900, 1000h) via on over-header hopper. Water was supplied *ad libitum*.

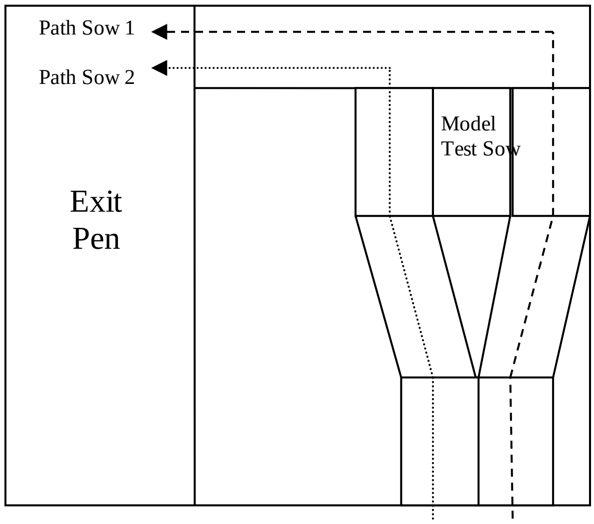

Figure 3 - Stalls-test

Measurements

Cortisol concentrations

Blood samples were taken on the day after mixing (Day 2) and Day 24 at approximately 12:00 h by venipuncture of the jugular vein. A 6 mL sample was taken in a heparinised tube (BD Vacutainer® BD, Belliver Industrial Estate, Plymouth, UK). For each animal, a maximum of 2 min was allowed to obtain the sample, to avoid an acute stress response associated with handling and blood sampling.

The individual samples were centrifuges at 7000 rpm and the plasma poured off and stored at -20°C until analysed. Plasma cortisol was measured using a commercial radioimmunoassay kit (Cortisol GammaCoat RIA kit CA-1549, Dia Sorin Inc., Stillwater MN, USA).

Behaviour

Aggressive behaviours considered as aggressive are defined in Table 12. The number of aggressive acts delivered and received by each individual pig during the observation period was recorded. Fights were classified as aggressive interactions involving the same pair of animals that exceed five seconds, and were recorded as one act of aggression delivered and received for both individuals in the fight and for every 5 s lapsed. Only when the full head of the attacking animal and the identifying symbol of the aggression delivering/receiving animal were clearly in the field of view were aggressive interactions recorded.

Aggressive behavior (aggression delivered and aggression received) of individuals was observed after mixing, and after each of four feed drops on Days 2 and 24 post-mixing. Mixing aggression was recorded using continuous sampling for 60 min after the 10th and final pig was added to the pen and the gate closed. Aggression at feeding was recorded using continuous sampling for 15 min after each of four daily feed drops.

From the observations on aggressive behaviour at Day 2, the aggression index for each sow was calculated as the ratio of aggression delivered to the total number of aggressive interactions (i.e., aggression delivered/(aggression delivered + aggression received)). The aggression index at Day 2 was used since aggression between group-housed sows that are restrictively fed is most pronounced early after grouping (Arey and Edwards, 1998; Barnett et al., 2001). Using these data, sows were classified as dominant (D), subdominant (SD) or submissive (SM) (see statistical analysis).

Table12 - Ethogram of behaviours classified as aggressive behaviour

Behaviour	Description
Parallel pressing	Pigs stand side by side and push with shoulders against each other, throwing the head against the neck or head of the other
Inverse parallel pressing	Pigs face front to front and then push their shoulders against each other, throwing the head against the neck and flanks of the other.
Head to body knocking	A rapid thrust upwards or sideways with the head or snout against any part of the body behind the ears. Most of the knocks are performed against the front half of the receiver. The performers mouth is shut.
Head to head knocking	A rapid thrust upwards or sideways with the head or snout against the neck, head or ears of the receiver. The performer's mouth is shut.
Bite	A pig delivers a knock with the head against the head, neck or body of the other pig with the mouth open.
Fights	One or a combination of above aggressive behaviours that exceeds 5 seconds.

Skin Injuries

The same assessment described by Karlen et al. (2007) was used to describe skin injuries for individual sows. Skin injuries were categorized into fresh injuries (scratches, abrasions, cuts, and abscesses), or partially healed or old injuries. Each side of the sow's body was divided into 21 areas as shown in Fig. 3 and described as follows: face (1), ear (2), neck (3), throat (4), processi scapulae (5), elbow (6), carpus (7), fetlock (8), coronary edge of the foreleg (9), hoof of the foreleg (10), sole of the foreleg (11), accessory digits of the foreleg (12), back and flank (13), tail and vulva (14), stifle (15)m hock (16), coronary edge of the back leg (17), hoof of the back leg (18), sole of the back leg (19), accessory digits of the back leg (20), and udder (21). The number and type of skin injuries were recorded on Days 2 and 24.

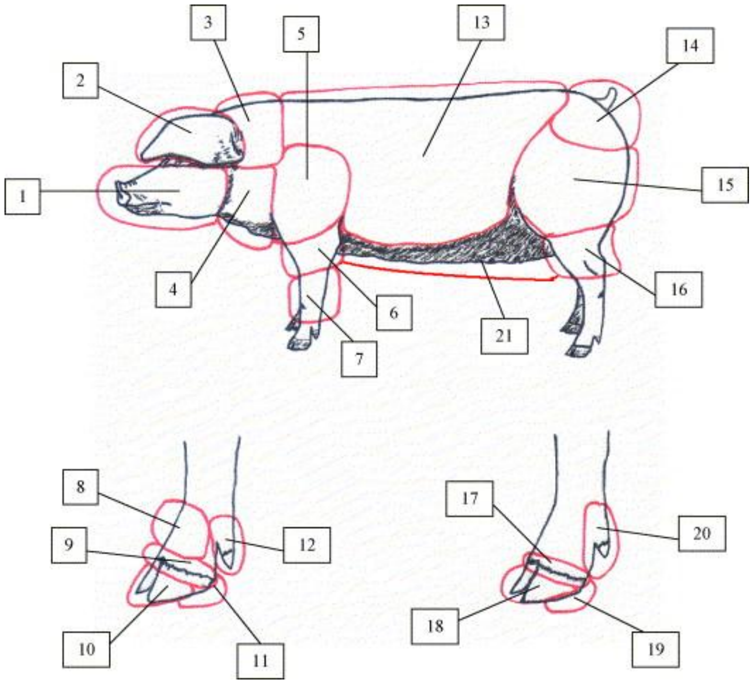

Figure 3 - Divisions of the surface of the sow where injures will be assessed (Karlen et al., 2007)

Productivity and other measures

Live weight gain

Sow were weighed on the day after mixing and Day 100, one week before being moved into the farrowing house. From this a live weight gain for the gestation was calculated.

Reproductive Performance

All sows farrowed in a common farrowing environment. The reproductive performance data collected allowed the following aspects to be calculated: farrowing rate and litter size (born alive and total born). Data on returns to oestrus, NIPs ("not-in-pig sows", that is, sows confirmed pregnant but failed to farrow), uro-genital infectious discharges and abortions were also collected.

Statistical Analysis

Forty-four unproductive sows were removed from the experiment between mixing and Day 24. Residuals were examined following a preliminary analysis using raw values, and if necessary to meet the variance criteria for an analysis of variance, data were transformed prior to a second analysis. This resulted in cortisol data being log10(X+1) transformed, and behaviour and injury data being square-root(X+1) transformed. Data that were greater than the 75th percentile plus 1.5 x the interquartile range (IQR), or less than the 25th percentile minus 1.5 x ICR were removed as statistical outliers for the following variables; live weight gain, plasma cortisol, litter size (total and born alive).

Due to unforeseen circumstances, there were inconsistencies in the frequency with which feed was delivered. Consequently two variables, aggression delivered and aggression received per feed drop, rather than aggression delivered and aggression received per day was used. These variables aggression delivered and aggression received per feed drop are referred to in this experiment as aggression delivered and aggression received.

The aggression index for sows, calculated as the ratio of aggression delivered to the total number of aggressive interactions, varied from 0 to 1. Using the aggression index, animals were classified as dominant if they delivered more aggression that what they received (aggression index > 0.5), subdominant if the received more aggression than what they delivered (aggression index <0.5), and submissive if they delivered no aggression (aggression index = 0) at feeding (see Experiment 2 for more background).

The Kappa statistic was calculated to determine the level of agreement in the sow classification on Days 2 and 24. In addition, a chi-square test was performed to determine whether dominant, subdominant and submissive classifications were distributed differently across the two treatments.

The group was the experimental unit for treatment comparisons of aggressive behaviour and welfare outcomes. Group means were analysed by an univariate analysis of variance (SPSS statistical package, SPSS 17.0, SPSS Inc., Chicago, Illinois, USA). The model included the starting fortnight as a blocking factor and parity as a covariate. When a dependent variable was examined at more than one time point during gestation, separate analyses were conducted at each stage of gestation.

Results

The level of agreement between aggression classification on Days 2 and 24 was low (Kappa=0.352, p<0.001). While the P value is significant (i.e., there is little chance that the statistic has been presented by chance), the magnitude of the statistic indicates that the level of agreement is low.

The distributions of sows in submissive, subdominant and dominant classifications in the two treatments are presented in Table 13. The lack of significant associations between treatment and distribution of classifications (at mixing, x^2 (df=2, n=360)=0.910, P=0.634; Day 2, x^2 (df=2, n=358)=0.09, p=0.956; Day 24 (x^2 (df=2, n=316)=0.397, P=0.820) indicates that similar distributions of submissive, subdominant and dominant sows existed in both treatments.

As shown in Table 14, there were no effects on aggression delivered or received, aggression index, injuries, cortsiol concentrations or reproductive performance.

Table 13 - The distribution of sows into submissive, subdominant and dominant classifications (frequency and % of total within treatment) at mixing and on Days 2 and 24 for both treatments

Treatment	SM	SD	D
At mixing (n=360)			
Aggressive	35 (19.4%)	83 (46.1%)	62 (34.4%)
Mixed	41 (22.8%)	75 (41.7%)	64 (35.6%)
At Day 2 (n=358)			
Aggressive	54 (30.0%)	63 (35.0%)	63 (35.0%)
Mixed	52 (29.2%)	65 (36.5%)	61 (34.3%)
At Day 24 (n=316)			
Aggressive	45 (27.8%)	62 (38.3%)	54 (34.0%)
Mixed	38 (24.7%)	62 (40.3%)	54 (35.1%)

Table 14 - The effect of treatment on welfare and productivity variables. Means (with back transformed means in parentheses) and standard errors (for transformed data in parentheses and in italics) are presented.

	Group composition			
	Aggressive	Mixed		P value
*Aggression Delivered**				
Mixing	4.96 (25.6) *(0.39)*	4.17 (18.4) *(0.28)*	$F_{1,28}$=1.50	0.232
Day 2	1.89 (4.57) *(0.08)*	1.96 (4.84) *(0.11)*	$F_{1,28}$=0.488	0.491
Day 24	1.99 (4.96) *(0.04)*	1.98 (4.92) *(0.07)*	$F_{1,28}$=0.003	0.959
*Aggression Received**				
Mixing	4.37 (20.1) *(0.32)*	3.77 (15.2) *(0.23)*	$F_{1,28}$=1.34	0.257
Day 2	1.86 (4.46) *(0.08)*	1.90 (4.61) *(0.11)*	$F_{1,28}$=0.309	0.583
Day 24	1.98 (4.92) *(0.04)*	1.96 (4.84) *(0.07)*	$F_{1,28}$=0.040	0.958
Aggression index				
Mixing	0.36 *(0.01)*	0.36 *(0.02)*	$F_{1,28}$=0.043	0.837
Day 2	0.37 *(0.02)*	0.37 *(0.02)*	$F_{1,28}$=0.001	0.971
Day 24	0.36 *(0.02)*	0.38 *(0.02)*	$F_{1,28}$=0.814	0.375
*Fresh Injuries**				
Day 2	4.30 (19.5) *(0.26)*	4.34 (19.8) *(0.29)*	$F_{1,28}$=0.00	0.996
Day 24	4.24 (19.0) *(0.26)*	4.13 (18.0) *(0.25)*	$F_{1,28}$=0.226	0.639
*Total Injuries**				
Day 2	4.74 (23.5) *(0.26)*	4.70 (23.1) *(0.27)*	$F_{1,28}$=0.150	0.702
Day 24	5.42 (30.4) (0.37)	5.19 (27.9) (0.25)	$F_{2,196}$=0.882	0.356
*Cortisol (mmol/L)***				
Day 2	1.56 (37.3) *(0.03)*	1.51 (33.4) *(0.04)*	$F_{1,28}$=0.364	0.551
Day 24	1.56 (37.3) *(0.03)*	1.59 (39.9) *(0.03)*	$F_{1,28}$=0.094	0.761
Live Weight Gain	62.4 *(2.09)*	58.6 *(2.26)*	$F_{1,28}$=0.341	0.564
Farrowing rate (proportion)	0.799 (0.1599)	0.839 (0.1335)	$F_{1,28}$=0.770	0.389
Litter size				
Total	12.1 *(0.32)*	12.0 *(0.27)*	$F_{1,28}$=0.001	0.977
Born Alive	11.0 *(0.29)*	10.9 *(0.23)*	$F_{1,28}$=0.004	0.953

*Aggression delivered/received and lesion data were square root transformed prior to statistical analysis. **Cortisol concentrations were log_{10} transformed prior to statistical analysis.

Discussion

While the two treatment groups were assembled on the basis of differing composition, that is sows of high predicted aggression and sows randomly selected, surprisingly the distribution of sows in the three categories of aggression at Day 2, Submissive, Subdominant and Dominant, did not differ between treatments. The low level of agreement between sow classification on Days 2 and 24 could be attributed to the changing nature of aggression with time (Karlen et al., 2007) and a reduced need to use aggression due to the regulation of a stable hierarchy using an "avoidance order" (Broom and Fraser, 2010; Keeling and Gonyou, 2001). Furthermore, there were no treatment effects on aggressive behaviour at Days 1, 2 and 24. It should be recognized that based on the results of the first experiment, that there is an 84% chance that those females selected as Dominant or Subdominant will actually be Dominant or Subdominant and conversely a 16% chance that they will be Submissive animals. Thus interpretation of treatment effects in the present experiment should be moderated by the possible presence of one Submissive animal in each of the groups of 10 Dominant animals. Nevertheless, there was not even a slight indication for any of the variables studied that aggression (and other welfare variables) was higher in the Dominant groups.

Individual variation in the aggressive behaviour of pigs has been well documented (Mount and Seabrook, 1993; Mendl, 1992; Verdon and Hemsworth, 2011; Hansen et al., 1982; Ruis et al., 2002; D'Eath et al., 2009; Turner et al., 2009; Zanella et al., 1998). However, this experiment found no significant differences in the aggressive behaviour or welfare outcomes of sows assembled into groups of either heterogeneous or homogenous aggressive animals. This contrasts with previous findings in young pigs, where it was found that mixed aggression groups had improved welfare and reduced aggression in comparison to either uniform high or low aggression groups (Erhard et al., 1997; Ruis et al., 2002; D'Eath et al., 2009; Hayne and Gonyou, 2006). These experiments on young pigs differ from this experiment, and from each other, in terms of the number and sex of animals used as well as how groups were composed and what welfare outcomes were measured, although the most significant cause for contrasting results is probably due to age differences. Under natural conditions young pigs learn social behaviour and their dominance status from similarly aged or older individuals (D'Eath and Turner, 2009). Under commercial conditions, however, young pigs lack the exposure to older individuals and thus their perceived status may remain unclear. As a result, ensuring behavioural variation exists within groups over time may provide pigs with the experience of effective defeat and victory, thus allowing them to assess differences in their relative competitive abilities and more quickly recognize their position in the present dominance hierarchy. In comparison to young pigs, however, sows are more socially experienced and as such are more likely to be both aware of their own fighting abilities and effective in assessing the fighting ability of others. As a result, the sow may assess the likelihood of winning an aggressive interaction based on the size or strength of her competitor, as well as experience, and show behavioural flexibility in regard to whether she then engages in aggression. Thus the aggressive behaviour of an individual sow may be dependent on her evaluation of the likelihood she could win an aggressive interaction, as well as her pre-disposition to aggression. However, due an inability of the model sow test to predict non-aggressive animals, this experiment examined only an aggressive homogeneous treatment.

An alternative explanation for the lack of significant treatment effects in the present experiment is poor prediction of aggression. The behavioural test used to identify aggressive animals was only studied in gilts and first-parity sows. As mentioned above, a predictive test that relies on the social interaction of the sow to an unfamiliar social stimulus may be more effective in older, more experienced, sows that may be better assessing a competitive social situation and deciding whether or not to engage in the competition. Indeed in mice Kudrvavtseva et al. (2004) showed that those who lose an aggressive interaction are less likely to engage in ensuing aggression of a similar nature. Furthermore, even with gilts and first-litter sows the behavioural test was only moderately predictive of aggressiveness early after grouping.

Conclusion

In conclusion, manipulating the group composition based on predicted sow aggressiveness to form groups of high or mixed aggression had no effect on either aggression delivered or received, aggression index, injuries, cortisol concentrations or reproductive performance. This contrasts with previous studies in young immature pigs, however both the social behaviour and social experience of sows are markedly different to that of younger pigs. Thus it appears that although sows vary in terms of individual aggressive characteristics, the tendency to show aggression is less important than the behaviour of others in the group. When fighting has significant costs, such as when sows are housed with older sows, otherwise aggressive sows may show flexibility in their use of aggression, opting out of aggressive interactions.

The normal social behavioural repertoire of modern domestic pigs comprises ancestral behaviour patterns exhibited when pigs were provided with adequate space and access to diverse resources. The extent to which these social behaviour patterns are expressed by the sow is likely to depend not only on their housing including characteristics of their group-mates and access to resources but also on genetics, previous experience including during rearing, possibly environmental conditions during embryonic development, and epigenetic effects.

5. Outcomes

The main findings are:

- Significant relationships were found between the behavioural response of female pigs to a social stimulus prior to mixing and aggressive behaviour when mixed in the first and second gestations. The correlations were most pronounced in sows than gilts.
- The repeatability of one of the key measures in this predictive test, the latency to snout contact, was moderate from the first to second parity. However, its repeatability from selection to the first and second parity was poor.
- The aggressive behaviour of gilts and first-litter sows early after mixing was related to their subsequent aggression in both gestations, although the relationships were stronger in the second gestation than the first.
- The aggressive behaviour of gilts and first-litter sows early after mixing was related to subsequent total and fresh injuries, cortisol concentrations, weight gain during gestation and the number of piglets born alive.
- Manipulating the group composition based on predicted sow aggressive behaviour to form groups of high or mixed aggression had no effect on aggression delivered or received, aggression index, injuries, cortisol concentrations or reproductive performance.

6. Application of Research

The interpretations from these findings are:

- **Significant relationships were found between the behavioural response of female pigs to a social stimulus prior to mixing and aggressive behaviour when mixed in the first and second gestations.** The correlations were most pronounced in sows than gilts, suggesting that aggressive behaviour is strongly influenced by experience. Used with caution, this predictive test may be useful in understanding the likely aggressive behaviour of individual females when subsequently mixed, particularly in sows, as well as providing an insight into the impact of group composition on aggression and welfare of individual group-housed sows.
- **The repeatability of one of the key measures in this predictive test, the latency to snout contact, was moderate from the first to second parity. However, its repeatability from selection to the first and second parity was poor.** The finding that the repeatability of this variable from the first to second parity was moderate, suggests that animals may need to be scored at least in adulthood after experience of grouping or several times to assess their 'true aggressive phenotype'.
- **The aggressive behaviour of gilts and first-litter sows early after mixing was related to their subsequent aggression in both gestations, although the relationships were stronger in the second gestation than the first.** These results indicate that aggressive behaviour is repeatable within gestations but less so between gestations and while it is most likely that there are both genetic and experiential effects, aggression of individual sows is likely to be affected by the aggressive behaviour of other sows in the group.
- **The aggressive behaviour of gilts and first-litter sows early after mixing was related to subsequent total and fresh injuries, cortisol concentrations, weight gain during gestation and the number of piglets born alive.** These results indicate that female pigs that engage in aggression at mixing and gain dominance have less injuries and possibly less stress. Their increased weight gain and litter size may be due to increased feed intake through priority access to feed and/or less stress. Furthermore, there is evidence that the most aggressive sows had higher litter sizes (born alive). Thus the aggressive behaviour of the female pig at mixing is an important determinant of her subsequent welfare and productivity.
- **Manipulating the group composition based on predicted sow aggressive behaviour to form groups of high or mixed aggression had no effect on aggression delivered or received, aggression index, injuries, cortisol concentrations or reproductive performance.** Thus it appears that although sows vary in terms of individual aggressive characteristics, the tendency to show aggression is less important than the behaviour of others in the group. When fighting has significant costs, such as when sows are housed with older sows, otherwise aggressive sows may show flexibility in their use of aggression, opting out of aggressive interactions.

7. Conclusion

It is concluded that:

- the behavioural response of female pigs to a fibreglass model sow before mixing is related to aggressive behaviour of females mixed in groups in the first and particularly second gestations. This behavioural test, based on the response of female pigs to a social stimulus, appears to be a useful predictive test of the aggressive behaviour of sows mixed in groups.
- while individual aggressive behaviour is repeatable within gestations, it is less repeatable between gestations. The reduced repeatability between gestations is likely to be due to both experience and group composition affecting the aggressive behaviour of individual sows. Indeed mixing females either of predicted high levels of aggression (homogenous groups) or mixing randomly (heterogenous groups) had little effect on aggression or welfare and production outcomes.
- the aggressive behaviour of female pigs appears flexible, changing with both social experience and group composition and consequently suggests that a behavioural test that predicts 'aggressive motivation' may be less useful as a selection tool for use on young pigs although there is consistent evidence that aggression in young pigs is moderately heritable. The value of this predictive test clearly requires further evaluation, particularly since the present results show that the predictive test was most predictive for experienced sows and less for young gilts.

8. Limitations/Risks

There are few immediate practical implications of this research, rather the research highlights to industry the variation that exists in individual sow aggression and consequently the welfare and productivity implications for the individual. While group housing of sows allows all more freedom of movement, exploration and socialization, a few may suffer from excessive aggression, injuries and stress. Consequently it raises the question of what welfare priority should be attached to different classes of animals: the majority, the most vulnerable, the most productive, etc. Furthermore, as industry moves towards group housing of sows and away from stall housing, animal rights and animal welfare groups are likely to turn their attention to sow aggression. Obviously from an industry perspective overall productivity is a financial imperative. The idea that economics is a consideration in animal welfare debates is distasteful for many however, economics is utilised as society makes decisions about using resources, which may be scarce or there may be competing demands for them, to achieve things it wants (Bennett, 1997). Nevertheless, other considerations such as economics, environmental, social and cultural, need to be balanced to ensure that the most vulnerable animals do not suffer.

9. Recommendations

It is recommended that

- discussion with geneticists on the value of this 'aggressive motivation' test is required. While repeatability was poor from selection to the first and second parity, repeatability from the first to second parity was moderate, which suggests that animals may need to be scored several times in this test to assess their 'true aggressive phenotype'. Obviously discussions with geneticists are required to explore firstly, the potential of this 'aggressive motivation' test relative to other recent and on-going developments in this area and secondly, the need for further development of this 'aggressive motivation' test in a genetic improvement programme.

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