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Reducing post-mixing aggression and skin lesions in weaned pigs by application of a synthetic maternal pheromone

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Abstract

In commercial pig production, piglets are often mixed after weaning which can result in severe aggression and lead to body damage, disruption of feeding behaviour and reduced growth. This experiment investigated whether application of a synthetic maternal pheromone to groups of weaned pigs in commercial housing would affect the level of aggression and skin lesions sustained after mixing. Two treatments (Pheromone and Control) were used with 16 replicate pens of pigs (20 pigs per pen). Treatments were applied on the day of weaning (average 28 days of age) on a per room basis in alternate weeks. In Pheromone pens, after routine washing and disinfection, the walls and feeders were treated one hour prior to occupation with a synthetic pheromone at a rate of 1.0 ml pig^{-1}. Control pens were as for Pheromone except no product was applied. During the 24-h period, post mixing, pigs in pheromone-treated pens spent significantly less time fighting than those in control pens. This was reflected in reduced injury scores 24 h after mixing, with pigs in pheromone-treated pens having 39% fewer skin lesions on the front of the body compared to those in control pens. Treatment had no effect on growth rate or feed efficiency, although the feed intake for days 7–28 was significantly lower and feed efficiency tended to be lower in pheromone-treated pens. In conclusion, application of a synthetic maternal pheromone can be considered one of the arsenal of strategies to reduce aggression and safeguard the welfare of groups of weaned pigs where mixing is unavoidable.

Keywords: *aggression, animal welfare, behaviour, pheromone, pig, weaning*

Introduction

Mixing pigs from different litters or groups is not recommended due to the risk of aggression between unfamiliar individuals. In the EU, for example, current legislation for the welfare of pigs (Commission Directive 2001/93/EC; EU 2001) requires that weaners and rearing pigs 'should be kept in groups with as little mixing as possible'. However, under commercial conditions, mixing pigs from different litters often occurs at weaning, typically because group size in weaner housing systems tends to be larger than average litter size. Similarly, groups of pigs of relatively even number are needed to conform to the constraints of fixed-pen dimensions and so make most efficient use of available housing. Some producers also mix litters at weaning in order to form groups with reduced liveweight variation to facilitate batch management and optimisation of dietary inputs. The resulting aggression can be severe between unfamiliar piglets (Friend *et al* 1983; Fraser *et al* 1998) and may result in skin lesions (McGlone 1985; Turner *et al* 2006), disruption of feeding behaviour and, as a consequence, reduced growth rate (growth check) (Pajor *et al* 1991) to varying degrees. Hence, minimising aggression between piglets may help alleviate some of the stress of the weaning process, and the post-weaning growth check often associated with it (Parratt *et al* 2006).

A range of different techniques have been investigated which might help piglets to adapt to the weaning process. Strategies employed prior to weaning include: promotion of early play experience with littermates to increase their ability to cope with stressors (Donaldson *et al* 2002); offering piglets from different litters the opportunity to socialise with each other prior to weaning (Wattanakul *et al* 1997; D'Eath 2005), with or without the presence of a sow (Parratt *et al* 2006) and altering the time of day at which weaning takes place (morning as opposed to evening) (Ogunbameru *et al* 1992). After the event of weaning itself, different forms of environmental enrichment have been investigated, including the provision of hides (McGlone & Curtis 1985) or temporary barriers within the pen (Waran & Broom 1993) as well as management changes such as grouping pigs according to different sizes (Andersen *et al* 2000) or by gender (ie single-sex groups) (Colson *et al* 2006). Interest has also been shown in manipulation of the olfactory environment by application of odour-masking agents (Friend *et al* 1983) or pheromones which disrupt the olfactory processes by which pigs recognise each other, thereby limiting post-mixing aggression (Marchant-Forde & Marchant-Forde 2005). Pageat and Teissier (1998) showed preliminary data

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indicating that a synthetic formulation of a maternal pheromone which closely matches the composition of skin secretions isolated from sows might reduce aggressive biting in pigs. McGlone and Anderson (2002) found that application of this putative synthetic maternal pheromone (either on the snout or on the feeder) did indeed reduce aggressive biting in piglets after weaning. Feeding behaviour was also stimulated, and there were significant improvements in growth rate and feed conversion efficiency in the pheromone treatment. However, the study by McGlone and Anderson (2002) was undertaken under small-scale experimental conditions with just three pigs per pen. The results may therefore not be directly applicable to commercial pig production where, for the sake of housing costs and ease of management, group size at weaning is usually much greater. Hence, the aim of the current experiment was to test whether application of a synthetic maternal pheromone to pens of weaned pigs, under typical commercial conditions, would affect the level of aggression, skin lesions, feed intake and growth performance after mixing.

Materials and methods

Experimental design

This pilot study was conducted at Cockle Park Farm, Morpeth, UK, a facility for applied research in pig science. A commercial-specification weaner building was used, consisting of six identical rooms each with four pens and designed to accommodate pigs for a period of five weeks. Each week, a newly-weaned batch of piglets was allocated to the four pens in one room (20 pigs per pen). There were two treatments (Pheromone and Control) each with 16 replicate pens per treatment (four rooms × four pens per room). Treatments were applied on a per room basis in alternate weeks for eight consecutive weeks. Thus, for the final two weeks, two rooms were reused after the previous batch of pigs had been moved out but, upon refilling, the room was allocated to the same treatment. In the Pheromone treatment, after routine washing and disinfection, on the day of weaning the walls and feeders of a standard pen were treated one hour prior to occupation with a synthetic pheromone (Suilence®, Ceva Sante Animale, France) according to the manufacturer's recommendations of 1.0 ml pig^{-1}. The pheromone contained liquid-soluble compounds found in the skin secretions of sows using a formula described by Pageat (2001) and was supplied as a microemulsion containing 20% (wt/vol) of the pheromonal fraction in an alcohol solution. Control pens were as for Pheromone, except nothing (neither product nor any carrier solution) was applied. Within a room, all four pens were treated in identical fashion to eliminate any possibility of pheromone diffusion between treatments.

Animals, housing and management

Large White × Landrace crossbred weaner pigs were weaned at approximately 28 days of age and allocated to treatment in groups of approximately 20 (± 2.1), range 17–23, balanced across treatments within a given week. According to standard operating practice for this farm, there were generally two different litters mixed together per pen. The pens were located in a conventional building for weaner pigs which consisted of a series of rooms, each with four pens measuring 1.86 × 3.44 m (length × breadth) (0.32 m^2 per pig). Pens had plastic, fully-slatted floors and solid partitions which prevented any physical or visual contact with animals in neighbouring pens. Temperature within the room was thermostatically controlled to maintain pigs at a temperature set initially at 26ºC, and then gradually reduced to 22ºC over the 28-day housing period. When required, additional heat was provided by heaters suspended above each pen. In each pen, water was provided from two nipple drinkers and feed from a plastic hopper with three feeding spaces. Pigs were fed *ad libitum* for a period of 28 days, using a series of three commercial diets appropriate for pigs of this age. Liveweight and feed intake were recorded on a pen basis for days 0 (weaning) to 7 and 7 to 28. The mean feed intake per pen was estimated from the record of feed supplied to each hopper in a given period from which was deducted the weight of any food remaining in the hopper at the time of weighing. Subsequently, the efficiency with which feed was converted into liveweight gain (food conversion ratio [FCR]) was calculated by dividing the amount of feed consumed by the total liveweight gain of the pen for a given period of time.

Behavioural measurements

Behaviour was recorded using a combination of direct and indirect observations. Using an ethogram of aggressive behaviours adapted from Turner *et al* (2006) (Table 1), the behaviour of each group of pigs was recorded by direct observation on day 1 (24 h after mixing) and day 7. One pen in each room was selected at random and observed for 60 min during which the number of instances of each of five behaviour categories was counted. Thus, for direct observations, n = 4 pens per treatment. For indirect observation, a video camera was positioned above every pen and behaviour during the 24-h period immediately after mixing recorded on a time-lapse video recorder. Subsequently, the number of pigs engaged in each of four general activity patterns (feeding, drinking, lying, active; after McGlone & Anderson 2002) and five social behaviour categories (fighting, belly-nosing, anal sniffing, tail-biting and ear-biting; after Breuer *et al* 2003) were recorded (Table 2) using scan samples at ten-minute intervals. The proportion of total observation time pigs spent in each behaviour in each pen was calculated over the 24-h period (out of the total of 144 scans). For each treatment, four pens were observed in each of three rooms, the data for the fourth room being lost due to video equipment failure. Thus, n = 12 pens per treatment for indirect observations.

Skin lesion counting

Skin lesion counts were recorded for each individual pig in each pen on three occasions, namely day 0 (prior to mixing), day 1 and day 7. For ease of assessment, the body of the animal was divided into three regions: front (head, neck,

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Table 1 Behaviour ethogram for direct observations on days 1 and 7 (adapted from Turner *et al* 2006).

Category	Definition
Fighting and biting	Periods of interaction during which bites were delivered to another pig which may or may not retaliate.
Push	Pig pushing another pig by moving nose/head actively up and down towards it.
Chase	A pig was moving quickly after another pig.
Mount	Pig was standing on hindlegs with its forelegs resting on another pig.

Table 2 Behaviour ethogram for indirect observations for the 24-h period after mixing.

Category	Definition
General activity (after McGlone et al *2002)*	
Feeding	Head in feeder.
Drinking	Mouth on water dispenser.
Lying	In total, anywhere in pen, body in contact with floor.
Activity	Standing and walking.
Social behaviour (Breuer et al *2003)*	
Fighting	Biting, aggression towards another pen mate.
Belly-nosing	Sniffing, touching belly (area above the genitals) of another pig with snout.
Anal sniffing	Contact, manipulate anal area of another pig.
Tail biting/nosing	Manipulate, suck or chew tail of pen mate.
Ear biting/nosing	Manipulate, suck or chew ear of pen mate.

shoulders and forelimbs); middle (flanks and back) and rear (rump, hindlimbs and tail), according to the method of Turner *et al* (2006). The number of skin lesions on each pig was counted, whereby a lesion was classified as any cut/scratch found on the pig ranging from a scab, ie hard skin resembling a scratch, to a fresh wound, usually red-pink in colour. The severity of the lesions was not scored. An individual lesion was classified as any continuous wound and, if there was a break in the length of the wound of more than 1 cm, this was classified as a new lesion.

Statistical analyses

For all data analyses, the pen was considered the experimental unit. As this was a pilot study, replication was limited which reduced the power of the statistical analysis to detect significant differences between treatments. Those data which were normally distributed (liveweight, feed intake, FCR and some of the behavioural categories) were subjected to analysis of variance (ANOVA) using the General Linear Model command (GLM; Minitab Statistical Software, Release 14, State College, PA, USA) which took account of treatment and replicate (except behaviour data from direct observation in which case only treatment was fitted). Data which did not conform to a normal distribution were analysed using the non-parametric Kruskal-Wallis test.

Results

General activity patterns (video observation)

Table 3 shows the effect of pheromone application on general activity patterns and social activity during the 24-h period after mixing. The proportion of time spent active (standing or walking), feeding or lying was not significantly affected by treatment, nor was time engaged in the behaviour categories belly-nosing, anal sniffing, tail biting/nosing and ear biting/nosing. However, pigs in pheromone-treated pens spent significantly less time fighting and more time drinking compared to those in control pens (Table 3).

Aggressive behaviour (direct observation)

Aggressive behaviour observed 24 h after mixing showed no significant effect of treatment (Table 4). However, in pheromone-treated pens there tended to be lower instances of fighting and biting and chase. Direct observation on day 7 showed no significant effect of treatment on any of the behaviour categories, except for mounting which was significantly greater in the Pheromone treatment.

Skin lesions

The mean number of skin lesion counts was low on day 0 (prior to mixing), increased markedly on day 1 (24 h after

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Table 3 Effect of pheromone on proportion of time, over a 24-h observation period, spent in general activity patterns and fighting, obtained by indirect observation.

Proportion of time	Pheromone (n = 12)	Control (n = 12)	Pooled SEM	*F*-value	*H*-value	*P*-value
Lying†	78.64	79.66	0.861	0.70	–	ns
Active†	16.28	14.87	0.735	1.82	–	ns
Feeding†	2.81	3.16	0.284	0.76	–	ns
Drinking†	1.43	1.12	0.072	9.21	–	0.007
Fighting†	0.62	0.83	0.059	6.68	–	0.018
Belly-nosing‡	0.01 (0.00–0.00)	0.03 (0.00–0.10)	–	–	2.18	ns
Anal sniffing‡	0.00 (0.00–0.00)	0.01 (0.00–0.00)	–	–	1.00	ns
Tail biting/nosing‡	0.01 (0.00–0.00)	0.00 (0.00–0.00)	–	–	1.00	ns
Ear biting/nosing‡	0.24 (0.13–0.30)	0.32 (0.20–0.050)	–	–	2.13	ns

† Data to which parametric statistical tests were applied show mean (± SEM), df = 1, 20.
‡ Data to which non-parametric statistical tests were applied show median with inter-quartile range in brackets, df = 7.
ns = not significant, $P > 0.10$.

Table 4 Effect of pheromone on instances of different behaviour categories observed during 60 min of direct observation on days 1 and 7, post mixing.

Number of instances	Pheromone (n = 4)	Control (n = 4)	Pooled SEM	*F*-value	*H*-value	*P*-value
Day 1 (24 h, post mixing)						
Fighting and biting†	19.8	43.8	7.24	5.49	–	0.058
Push‡	1.0 (0.0–5.8)	5.0 (2.8–24.5)	–	–	1.75	ns
Chase‡	0.5 (0.0–1.0)	1.5 (1.0–3.5)	–	–	3.45	0.063
Mount†	23.3	34.3	10.05	0.60	–	ns
Day 7						
Fighting and biting†	9.3	13.5	4.25	0.50	–	ns
Push‡	2.5 (0.0–6.5)	3.5 (0.3–6.8)	–	–	0.20	ns
Chase‡	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–	–	0.00	ns
Mount†	22.3	8.3	1.53	10.07	–	0.019

† Data to which parametric statistical tests were applied show mean (± SEM), df = 1, 6.
‡ Data to which non-parametric statistical tests were applied show median with inter-quartile range in brackets, df = 7.
ns = not significant, $P > 0.10$.

mixing) and then reduced again on day 7 (Table 5). Although treatment had no significant effect on total lesion count on day 0, pigs in pheromone-treated pens had significantly more skin lesions on the front of the body compared to pigs in control pens. However, on day 1 (24 h post mixing), pigs in pheromone-treated pens had significantly fewer skin lesions (front, middle and rear) compared to those in control pens. Differences in the number of skin lesions between treatments were reduced by day 7, but were still significant for all but lesions on the rear of the animal (which tended towards significance, see Table 5).

Growth rate, feed intake and feed conversion efficiency

Application of the pheromone had no significant effect on liveweight, growth rate or feed conversion efficiency (Table 6). However, average feed intake for the period days 7–28 was significantly lower for pigs in the Pheromone treatment. There was a tendency for pigs in pheromone-treated pens to have a higher FCR value for the days 0–7 compared to those in control pens, although this was not significant.

Discussion

This experiment investigated whether application of a synthetic maternal pheromone to pens of weaned pigs under typical commercial conditions would affect the level of aggression, skin lesions, feed intake and growth performance after mixing.

Application of the pheromone to the pen walls and sides of the feeders resulted in a significant reduction in the level of aggression and skin lesions sustained by weaned pigs. In pheromone-treated pens, video observation in the 24-h period after mixing showed that time spent fighting was significantly less than in control pens, a reduction of 25%. This was confirmed by direct observation 24 h after mixing, where the incidence of fighting and biting was 55% lower

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Table 5 Effect of pheromone on number of skin lesions on different parts of the body determined on days 0, 1 and 7, post mixing.

Number of skin lesions	Pheromone (n = 16)	Control (n = 16)	Pooled SEM	*F*-value	*P*-value
Day 0 (pre mixing)					
Front	1.2	0.7	0.13	6.01	0.021
Middle	0.9	0.6	0.22	1.15	ns
Rear	0.2	0.3	0.09	0.70	ns
Day 1 (24 h, post mixing)					
Front	10.7	15.2	0.97	10.72	0.003
Middle	8.7	12.9	1.30	5.26	0.030
Rear	0.6	1.0	0.13	7.26	0.012
Day 7					
Front	1.4	2.3	0.23	8.33	0.008
Middle	0.7	1.4	0.25	4.28	0.048
Rear	0.1	0.4	0.08	4.03	0.055

df = 1, 27.

Table 6 Effect of pheromone on liveweight, growth rate and feed intake.

Parameter	Pheromone (n = 16)	Control (n = 16)	Pooled SEM	*F*-value	*P*-value
Liveweight (kg)					
Day 0	8.4	8.6	0.18	0.57	ns
Day 7	10.0	10.5	0.28	1.74	ns
Day 28	20.2	21.3	0.47	2.45	ns
Daily gain (kg per day)					
Day 0–7	0.22	0.27	0.023	2.04	ns
Day 7–28	0.49	0.51	0.012	2.03	ns
Feed intake (kg per pig per day)					
Day 0–7	0.26	0.25	0.024	0.15	ns
Day 7–28	0.46	0.51	0.013	6.79	0.015
FCR *(kg feed/kg gain)*					
Day 0–7	1.18	0.99	0.069	3.99	0.056
Day 7–28	1.25	1.31	0.038	1.50	ns

df = 1, 27.

than in control pens. Previous research by McGlone and Anderson (2002), using the same pheromone but with groups of only three pigs per pen, reported a similar level of reduction in aggression sustained over a 48-h period, post mixing. They recorded that, on average, the level of aggressive behaviour, including those behaviours classified by biting, pushing and thrusting against another pig, was 41% lower in two pheromone treatments (the pheromone was applied to either the pig's snout or the feeder) compared to control groups of pigs (linear contrast, $P < 0.05$). The components of this putative maternal pheromone have been identified in the three maternal fluids (amniotic fluid, colostrum and milk) known to evoke positive orientation of newborn piglets (Guiraudie-Capraz *et al* 2005). Housing pigs in an environment where the olfactory clues suggest that the sow is present may provide some sense of familiarity to the pig during periods of uncertainty (eg the introduction of new group members and/or a new pen) thereby reducing aggression. This is in accordance with McGlone and Anderson (2002) who, although they did not offer a detailed explanation of how the pheromone reduces aggression, hypothesised that its application 'reduced the stressfulness of weaning'. It is also possible that this synthetic pheromone suppresses aggression by indicating the

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presence of a larger, dominant animal (in this case a sow) which has been described previously in the literature. McGlone and Morrow (1988) reported that levels of aggression in piglets regrouped at 28 days of age were reduced when sprayed with androstenone, the male pheromone signalling boar presence, whilst Grandin and Bruning (1992) found that the presence of a sexually mature boar in pens of slaughter pigs, mixed prior to transport, reduced the incidence and severity of aggression. Hence, if the synthetic pheromone used in the current study acts simply as a cue for the perceived presence of a larger, dominant animal to suppress aggression, its use for older pigs in situations where mixing is unavoidable warrants further investigation.

On day 7 after mixing, mounting behaviour was seen significantly more in pheromone-treated pens than in control pens. Mounting can be regarded as a social manipulation behaviour, rather than an aggressive act (Dudink *et al* 2006). It could therefore be speculated that the reduced level of aggression in pheromone-treated pens resulted in the formation of a stable social hierarchy more quickly, by replacement of aggression with social manipulation behaviour.

The number of skin lesions on the body, 24 h after mixing, was considerably lower after pheromone application. In the literature there is general agreement that skin lesions are a reliable indicator of the duration and magnitude of behaviours causing physical injury to pigs and hence reflect the level of aggression in a group (eg Turner *et al* 2006). The most marked effect of pheromone application was in the reduction of skin lesions at the front of the body (mean number of skin lesions on the front of the pig was 39% lower in pheromone-treated pens than in control pens). Turner *et al* (2006) point out that skin lesions on the front of the body are particularly associated with two-sided reciprocal aggression, one of the main aggressive behaviours which occurs at weaning. Therefore, reduction in the number of skin lesions in pheromone-treated pens closely maps the reduction in aggressive behaviour demonstrated by behaviour observations. Reduction in skin lesions for pheromone-treated pens was apparent even after 7 days, post mixing (a 30% reduction in number of lesions on the front of the body).

McGlone and Anderson (2002) also recorded that pigs in pens where the pheromone was applied to the feeder spent significantly more time feeding (defined as head in the feeder) than in the control group, although this was not matched to data for food disappearance from the feeder. These authors maintained that application of the pheromone to the feeder stimulated the behaviour of weaned pigs in a 'more desirable manner', namely causing decreased aggression and time spent playing with the drinkers and increased feeder exploration. McGlone and Anderson (2002) maintained that the absence of a significant effect of treatment on feed intake was due to the considerable variation in apparent feed intake data associated with weaned pigs, as they play and root in their feed as part of the process of learning to consume dry feed.

In the current study, whilst there was no significant effect of treatment on time spent feeding (defined as head in the feeder), mean feed intake (measured as food disappearance from the feeder) was lower for pheromone-treated pens in the period from day 7 to 28, post-weaning. This differs from the study by McGlone and Anderson (2002) who reported that pheromone treatment resulted in an increase in feeding behaviour. In the current experiment, to ensure a wider distribution of product within the larger group conditions, the pheromone was applied to the sides of the pen as well as the outside of the feeder at the manufacturer's recommended rate of 1 ml pig^{-1}. McGlone and Anderson (2002) however applied the equivalent of 10 ml pig^{-1} solely to the feeding trough and lip of the feeder. Hence, it is perhaps unsurprising that wider pheromone application to pens under commercial conditions did not result in a stimulatory effect on feeding behaviour.

In contrast to McGlone and Anderson (2002), in the current study there was no improvement in growth rate following application of pheromone. However, the effects of stress reduction on performance may be greater if pheromone application is used to limit aggression in conditions where, on commercial farms, standards of housing and animal husbandry may impose greater health or environmental challenges than were experienced by pigs in this study. There is some evidence in the literature, mainly from studies with rodents, to suggest that aggression and health are linked. In their review, Azpiroz *et al* (2003) reported that some, but not all, studies support the hypothesis that low social ranking, submissive social status or subjection to threat/attack is linked to a state of immunodepression.

The experimental design used in the current study was limited in that the pheromone treatment was a combination of pheromone plus carrier alcohol solution, a true control would have been application of the carrier alcohol alone. However, in their study, McGlone and Anderson (2002) used application of alcohol solution as a control and found that levels of aggression were reduced only in treatments that received pheromone plus alcohol carrier.

Conclusion and animal welfare implications

Although conducted with limited numbers of animals, this pilot study provides evidence that under commercial conditions the application of a synthetic maternal pheromone leads to reduced levels of aggression and number of skin lesions sustained by weaned pigs, post mixing. Such modification of behaviour may lead to improvements in animal health and welfare.

In conclusion, data from this pilot study indicate that application of a synthetic maternal pheromone could be considered one of the arsenal of strategies to reduce aggression and safeguard the welfare of groups of weaned pigs in commercial conditions where mixing is unavoidable.

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References

Andersen IL, Andenæs H, Bøe KE, Jensen P and Bakken M 2000 The effects of weight asymmetry and resource distribution on aggression in groups of unacquainted pigs. *Applied Animal Behaviour Science 68*: 107-120

Azpiroz A, Garmendia L, Fano E and Sanchez-Martin JR 2003 Relations between aggressive behaviour, immune activity and disease susceptibility. *Aggression and Violent Behaviour 8*: 433-453

Breuer K, Sutcliffe MEM, Mercer JT, Rance KA, Beattie VE, Sneddon IA and Edwards SA 2003 The effect of breed on the development of adverse social behaviours in pigs. *Applied Animal Behaviour Science 84*: 59-74

Colson V, Orgeur P, Courboulay V, Dantec S, Foury A and Mormede P 2006 Grouping piglets by sex at weaning reduces aggressive behaviour. *Applied Animal Behaviour Science 97*: 152-171

D'Eath RB 2005 Socialising piglets before weaning improves social hierarchy formation when pigs are mixed post-weaning. *Applied Animal Behaviour Science 93*: 199-211

Donaldson TM, Newberry RC, Spinka M and Cloutier S 2002 Effects of early play experience on play behaviour of piglets after weaning. *Applied Animal Behaviour Science 79*: 221-231

Dudink S, Simonse H, Marks I, de Jonge FH and Spruijt BM 2006 Announcing the arrival of enrichment increases play behaviour and reduces weaning stress-induced behaviour of piglets directly after weaning. *Applied Animal Behaviour Science 101*: 86-101

EU 2001 *Commission Directive 2001/93/EC of 9 November 2001 Amending Directive 91/630/EEC Laying Down Minimum Standards for the Protection of Pigs*. European Commission: Brussels, Belgium

Fraser D, Milligan B, Pajor EA, Phillips PA, Taylor AA and Weary DM 1998 Behavioural perspectives on weaning in domestic pigs. In: Wiseman J, Varley MA and Chadwick JP (eds) *Progress in Pig Science* pp 121-140. Nottingham University Press: Nottingham, UK

Friend TH, Knabe DA and Tanksley TD 1983 Behaviour and performance of pigs grouped by three different methods of weaning. *Journal of Animal Science 57*: 1046-1411

Grandin T and Bruning J 1992 Boar presence reduces fighting in mixed slaughter-weight pigs. *Applied Animal Behaviour Science 33*: 273-276

Guiraudie-Capraz G, Slomianny M-C, Pageat P, Malosse C, Cain A-H, Orgeur P and Nagnan-Le Meillour P 2005 Biochemical and chemical supports for a transnatal olfactory continuity through sow maternal fluids. *Chemical Senses 30*: 241-251

Marchant-Forde JN and Marchant-Forde RM 2005 Minimising inter-pig aggression during mixing. *Pig News and Information 26*: 63-71

McGlone JJ 1985 A quantitative ethogram of aggressive and submissive behaviours in recently regrouped pigs. *Journal of Animal Science 61*: 559-565

McGlone JJ and Anderson DL 2002 Synthetic maternal pheromone stimulates feeding behaviour and weight gain in weaned pigs. *Journal of Animal Science 80*: 3179-3183

McGlone JJ and Curtis SE 1985 Behaviour and performance of weanling pigs in pens equipped with hides. *Journal of Animal Science 60*: 20-24

McGlone JJ and Morrow JL 1988 Reduction of pig agonistic behaviour by androstenone. *Journal of Animal Science 66*: 880-884

Ogunbameru BO, Kornegay ET and Wood CM 1992 Effect of evening or morning weaning and immediate or delayed feeding on post weaning performance of pigs. *Journal of Animal Science 70*: 337-342

Pageat P and Teissier Y 1998 Usefulness of a porcine pheromone analogue in the reduction of aggression between weaners on penning; behavioural study. *Proceedings of 15th International Pig Veterinary Society* pp 413. 5-9 July, 1998, Birmingham, UK

Pageat P 2001 *Pig Appeasing Pheromones to Decrease Stress, Anxiety and Aggressiveness*. US Patent Number 6,169,113. http://www.patents.com/Pig-appeasing-pheromones-decrease-stress-anxiety-aggressiveness/US6169113/en-US/

Pajor EA, Fraser D and Kramer DL 1991 Consumption of solid food by suckling pigs: individual variation and relation to weight gain. *Applied Animal Behaviour Science 32*: 139-155

Parratt CA, Chapman KJ, Turner C, Jones PH, Mendl MT and Miller BG 2006 The fighting behaviour of piglets mixed before and after weaning in the presence and absence of a sow. *Applied Animal Behaviour Science 101*: 54-67

Turner SP, Farnworth NJ, White IMS, Brotherstone S, Mendl M, Knap P, Penny P and Lawrence AB 2006 The accumulation of skin lesions and their use as a predictor of individual aggressiveness in pigs. *Applied Animal Behaviour Science 96*: 245-259

Waran NK and Broom DM 1993 The influence of a barrier on the behaviour and growth of early-weaned piglets. *Animal Production 56*: 115-119

Wattanakul W, Stewart AH, Edwards SA and English PR 1997 A study of the effects of grouping piglets and changing sow location on behaviour and performance of suckling piglets. *Applied Animal Behaviour Science 55*: 21-35

https://doi.org/10.1017/S096272860000049X Published online by Cambridge University Press