Developing commercially-viable, confinement-free farrowing and lactation systems

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Part 2: Utilising confinement-free systems to maximise economic performance. 'Two-stage' farrowing and lactation system.

Final report prepared for the

Co-operative Research Centre for High Integrity Australian Pork

By

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Executive Summary

The use of farrowing crates improves the welfare of neonatal pigs by providing warmth and limits the risk that piglets become chilled and die from either starvation or being overlain by the sow. Farrowing crates however, restrict the ability of the sow to move around and perform 'normal' maternal behaviours and have been criticised on welfare grounds. Recently, attempts have been made to describe the specific farrowing pen design criteria to meet those maternal needs, and commercially-viable confinement-free farrowing and lactation systems are being developed (e.g. the Norwegian UMB and the PigSAFE farrowing pens). Part 1 (Developing commercially-viable, confinement-free farrowing and lactation systems) of this project investigated the development of the UMB and PigSAFE farrowing pens for the Australian environment.

It is unlikely that any loose farrowing system will operate effectively in the footprint of an existing farrowing crate space. Minimal design criteria for space have been recommended based on behavioural needs, as well as the basic body dimensions of sows and piglets. Any effective pen design is assumed to require extra floor space and consequently added capital costs. An additional design would be to maximise throughput of sows through these 'high cost' systems. This experiment examined the use of a 'two-stage system', allowing farrowing in a specialised individual farrowing pen (the PigSAFE pen) or farrowing crate and then grouping animals into more cost-effective accommodation after approximately 14 days (i.e. multi-suckle or group lactation systems). The aim of this experiment was to investigate sow performance, sow welfare, piglet survival and growth and incidence of lactational oestrus in a two-stage farrowing and lactation system under Australian conditions between March and November.

Three hundred and sixty Large White x Landrace sows were housed in each of the following housing treatments; A: Farrowing crate until weaning , B: Farrowing crate - Group lactation (sows were moved into group lactation 14 days prior to weaning), C:PigSAFE until weaning or D: PigSAFE - Group lactation (sows moved to group lactation 14 days prior to weaning).

The 'two-stage' system has shown promise, as there was no significant difference in the piglet mortality over the whole farrowing and lactation period, number of piglets weaned and sow growth between housing systems. However, piglet growth rate and weaning weight was reduced and a higher percentage of piglets died (mainly due to being unthrifty) after being mixed into the group lactation system, which may be attributed to cross suckling, increased socialisation and activity, increased risk of being overlain by sows in the group and perhaps reduced sow feed intake. Further research is required to assess piglet survival, long-term implications of this growth-check in the piglets and assessing welfare of piglets both pre and post-weaning in group lactation systems. Overall, there was a trend for higher piglet mortality in the PigSAFE system which supports the need for further development of these loose farrowing systems under Australian conditions. The majority of piglet deaths in all housing systems occurred within the first two days post-partum.

Sows moved from the PigSAFE pens to a group lactation system had less fresh injuries (resulting from aggression) had lower salivary cortisol post-mixing and suckled their litter quicker than sows introduced to the group lactation pen from a farrowing crate 14 days prior to weaning. It is speculated that sows were familiar with each other (through the design of PigSAFE pen) and had more opportunity to bond with their piglets previously. There appear to be benefits of mixing familiar animals into group lactation systems. Over the remainder of the lactation period in group lactation there was reduced aggression and injury, indicating the sows had settled down.

Spontaneous lactational oestrus occurred in all housing treatments. Approximately 9% of sows in the farrowing crate treatment and 27% of sows in the PigSAFE and group lactation

treatments experienced lactational oestrus. However, these levels are not sufficient to enable producers to exploit the possible advantages of mating during lactation. A target level of 85% incidence of lactational oestrus is required in the herd before being able to be adopted as a viable alternate production system. It is speculated that the ability of the sow to naturally regulate nursing behaviour and wean piglets by avoidance in loose farrowing and group lactation environments may be implicated. If a ‘two-step’ system is further developed and lactational oestrus is viable to implement in such a system, then further research to induce lactational oestrus (i.e. piglet separation and boar exposure in group lactation) in the group pen situation, may be required. On the other hand, if mating during lactation is not desired by the pork producer, then producers need to be aware of and manage extended wean-to-remate intervals in a proportion of the sows and management strategies may need to be implemented to reduce the risks associated with sows showing signs of lactational oestrus in loose farrowing and lactation systems.

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1. Introduction

The use of farrowing crates can improve the welfare of neonatal pigs by providing warmth in a restricted space and limit the risk that piglets become chilled and die from either starvation or being overlain by the sow. Farrowing crates and the concomitant lack of nesting material, however, restrict the ability of the sow to move around and perform 'normal' pre-farrowing behaviours such as nest-site selection, nest-building activity and bonding with the piglets, and therefore have been criticised on welfare grounds. Recently attempts have been made to describe the specific farrowing pen design criteria to meet those needs, and commercially-viable confinement-free farrowing and lactation systems are being developed for Australian conditions (e.g. the Norwegian UMB and the PigSAFE farrowing pens) (Morrison *et al.*, 2013; Morrison and Cronin, 2013).

However, in order to satisfy piglet and sow biological needs it is unlikely that any confinement-free, loose farrowing system will operate effectively in the footprint of an existing farrowing crate space. Minimal design criteria for space have been recommended (Cronin, 2010; Baxter *et al.*, 2011a,b), based on behavioural needs (e.g. nest-building), as well as basic body dimensions of sows and piglets (Moustsen *et al.*, 2011). Any effective design is assumed to require extra space and consequently added capital costs. Ideally costs would be offset by increased production performance in terms of piglet survival, weaning weight or sow rebreeding efficiency and therefore the capital investment should achieve an acceptable return rate (Baxter *et al.*, *2012*). An additional consideration to re-coup initial investment out-lay would be to maximise throughput of sows through these 'high cost' systems. One proposition is to use a 'two-stage' system, allowing farrowing in a specialised individual farrowing pen (i.e. PigSAFE pen) and then grouping animals into more cost-effective accommodation after approximately 12 days (i.e. multi-suckle or group lactation systems).

Farrowing crates were banned in Sweden in the 1970's which resulted in the development of a number of loose farrowing and lactation systems. Common multi-suckle, group lactation systems include the Swedish systems – i.e. Thorstensson (Marchant *et al.*, 2001; Li *et al.*, 2010) or Ljungstrøm (Marchant *et al.*, 2000). The Thorstensson system involves grouping sows prior to farrowing with free access to individual nest boxes for farrowing, which may or may not be removed until 7-10 days post-farrowing. Alternatively the Ljungstrøm system individually houses sows in pens initially, then integrates them with their litter into groups in larger multi-suckling pens between 10-21 days post-farrowing. Rivalea have recently developed a group-lactation system, based on the Swedish designs, however modified to include pen design features to improve piglet survival (i.e. creep areas, bedded areas and sloped walls).

These group lactation systems differ in many aspects compared to more conventional farrowing systems. They provide more environmental complexity and more freedom of movement for maternal and social behaviours to be performed. There may be additional benefits, as integrating sows and piglets before weaning has been shown to reduce some factors associated with weaning stress; e.g. early socialisation of piglets reduces aggression at weaning (D'Eath, 2005) and piglets raised in group lactation may have improved social development (Verdon, 2013-unpublished-see Appendix 1). Social integration for the sows is also important to reduce aggression observed post-weaning when animals re-acquaint with each other and establish dominance.

However, group lactation poses some risks, such as disrupted nursing and increased levels of piglet crushing if there is aggression between sows. Cross suckling and disturbed nursings may impact on piglet survival and growth rate. Recently, the Swedish Ministry of Agriculture industry have identified a number of issues related to group lactation and is funding a new project to re-evaluate the use of farrowing crates in an attempt to improve piglet survival. Ingemar Olssson, Chairman of Sweden's pig producer's organization recently stated "Our farm animal protection laws are based on research from the mid-1980's. Times change, and the situation is different today. Such high mortality is not acceptable" (GlobalMeatnews.com, 2015). The use of the Rivalea 'two stage system', which utilizes components of the designed farrowing pen and a designed group lactation pen with features to protect piglets (i.e. sloped walls and creep areas) requires further investigation.

It is possible that sows farrowing in loose-housed accommodation (i.e. PigSAFE) and moving to group systems for lactation will adapt better than sows experiencing the same transition from conventional farrowing crated accommodation. Under natural or semi-natural conditions pigs maintain established groups where aggression is regulated via 'avoidance order', with specific behavioural patterns reducing risk of attacks by dominant individuals (Jensen, 2002). When a sow leaves the group to farrow, the longer she remains isolated, the more challenging it is for her and her litter to re-integrate. Under domesticated and intensive conditions where sows are housed in farrowing crates, sows are likely to be separated for at least 5 weeks during farrowing/lactation before re-grouping. Re-grouping may involve dynamic mixing (i.e. mixed with unfamiliar animals) and thus there is a high risk of damaging interactions after mixing. If the individual loose-housed accommodation allows 'fenceline social contact' (visual and physical), which occurs in the PigSAFE system, then this could help maintain or establish bonds and reduce aggression when mixed into group lactation. This requires further investigation.

The Australian pork industry is currently investigating strategies to induce lactational oestrus to enhance sow performance, extend the lactation period and eliminate the need for sow confinement (use of mating stalls) post-weaning (Downing *et al.*, 2012; Terry *et al.*, 2013). Studies funded by the Australian Pork Corporative Research Centre, indicated that 12 hours of piglet removal, from day 16 post-parturition onwards, and fence-line boar exposure stimulated a high proportion of sows to exhibit a rapid and synchronous ovulatory response during lactation (Downing *et al.*, 2012). There is anecdotal evidence and limited information in the scientific literature that shows that housing sows and litters in a group during lactation may also induce lactational oestrus (reviewed by van Nieuwamerongen *et al.*, 2014). Further research is required to assess the incidence of lactational oestrus in a group lactation system under Australian conditions.

The aim of this experiment was to investigate sow performance, sow welfare, piglet survival and growth and incidence of lactational oestrus in a two-stage farrowing and lactation system under Australian conditions.

2. Materials and Methods

This experiment was conducted between March and November 2014 in a farrowing house unit of a large commercial piggery in southern New South Wales, Australia. 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 Organisation/Australian Animal Commission *Code of Practice for the Care and Use of Animals for Scientific Purposes*. A total of 360 sows, over 6 time replicates were studied. Landrace × Large White sows of mixed parity (range: gilts-parity 5) that were of good health at the beginning of the experiment were included in the study. There were equal numbers of gilts allocated to each housing treatment in each time replicate.

Housing

There were three housing systems used in the experiment –

- farrowing crate system

- PigSAFE system
- group lactation system.

The three housing systems were located in adjacent sheds. The buildings were similar in terms of construction material. The buildings were open-sided with shutters and heating which enabled some temperature control. The farrowing crate shed contained 64 crates. Thirty crates were selected across the shed to be part of the experiment. The farrowing crates were 1.67m wide x 2.25m long. The farrowing crates contained a creep area using a mat below an overhead heat lamp. A water dripper for cooling was located above each sow. The PigSAFE shed contained 30 PigSAFE pens (Figure 1; Photograph 1). The PigSAFE pen contained a creep area using a heat mat below and an overhead heat lamp. In the PigSAFE shed, misters and fans were located above the dunging area for cooling. The group lactation shed contained two pens (Figure 2; Photograph 2). Each pen was 6m wide x 9.5m long. There were 6 sows and their litters in each pen (approximately 9.5m^2/sow/litter). There was one *ad libitum* sow feeder in the pen with feed access for 2 sows at a time. In the group lactation pens there were misters located above the dunging area for cooling.

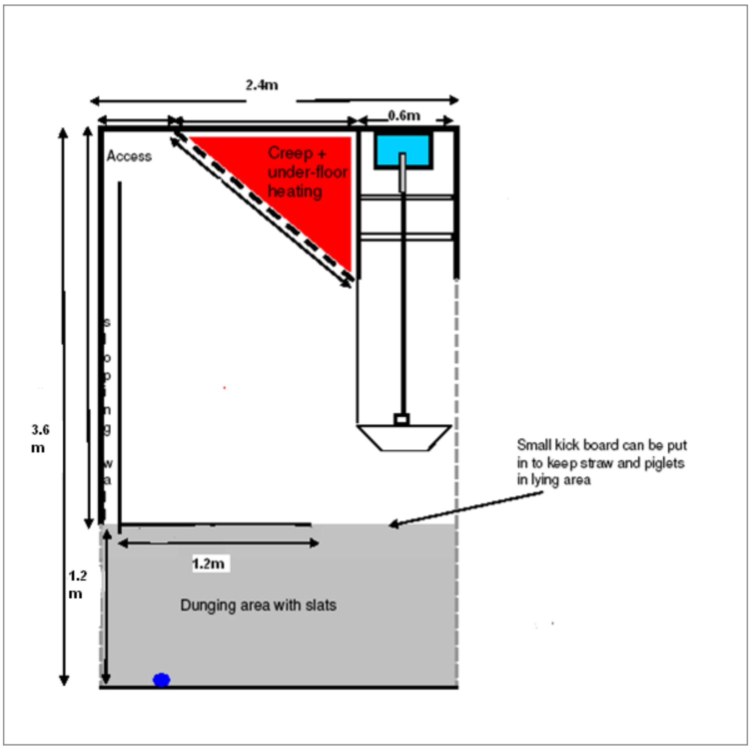

Figure 1 - Floorplan of the Rivalea PigSAFE farrowing pen.

Photograph 1 - The Rivalea PigSAFE farrowing pen.

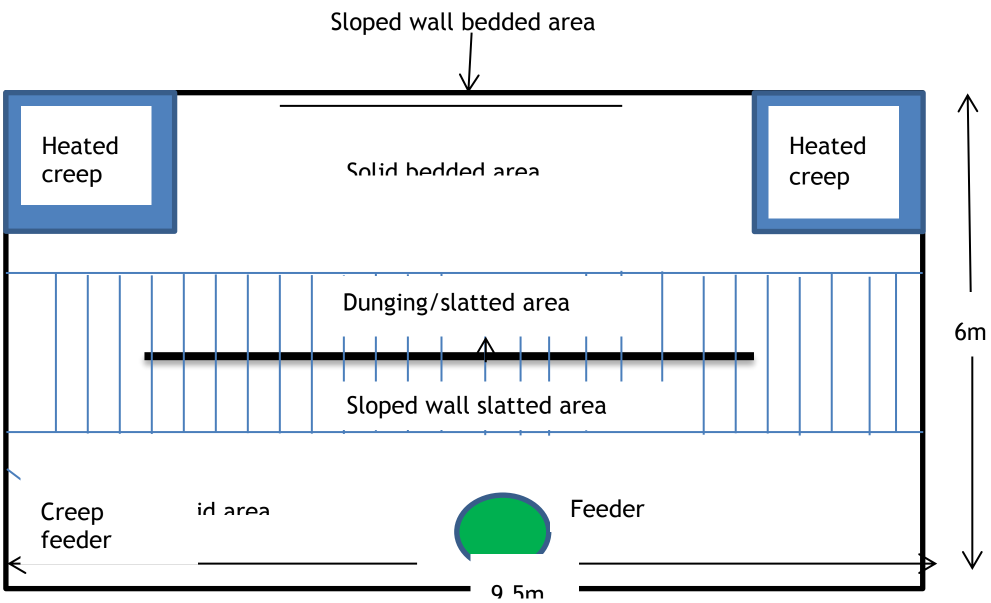

Figure 2 - Floorplan of the Rivalea group lactation farrowing pen.

Photograph 2 - The Rivalea group lactation farrowing pen

Housing treatments

- Farrowing crate (FC): Sows were housed in a farrowing crate until weaning (144 sows/treatment).
- Farrowing Crate-Group lactation (GL_{FC}): Sows were housed in a farrowing crate then moved into group lactation 14 days prior to weaning (36 sows/treatment).
- PigSAFE (PS): Sows were housed in PigSAFE until weaning (144/treatment).
- PigSAFE-Group lactation (GL_{PS}): Sows were housed in PigSAFE then moved to group lactation 14 days prior to weaning (36 sows/treatment).

Sows in all housing treatments were managed by the same stockpeople. Upon entry to the PigSAFE pen the sows were provided with a biscuit (2kg) of long cut straw for nesting. If the sow ate/removed the straw, additional straw was provided up until farrowing. Minimal fostering was conducted within the first 24hrs post-birth in all housing treatments. If possible the piglets were fostered within treatment. After farrowing, all sows were provided with a commercial lactation diet (14.9 MJ DE/kg and 16.2% crude protein) in a step-up program. By day 4 of lactation, sows were provided with *ad libitum* feed. Sows and litters in the GL_{FC} and GL_{PS} treatments were moved from their farrowing crate/PigSAFE pen into group lactation pens 14 days prior to weaning (average age of piglets was approximately 13 days). The sows were moved quietly into the group lactation pens and their piglets were moved in within the hour. Piglets in all housing treatments were offered creep feed from 13 days of age. Piglets were weaned at approximately 27 days of age in all treatments. At weaning, sows were moved into individual mating stalls and received boar exposure daily until insemination.

Measurements

Sow live weight and condition score and piglet weight

All of the sows were individually weighed, condition scored (Figure 3) and P2 backfat measured by ultrasound prior to entry to housing system (prior to farrowing), 14 days prior to weaning and at weaning. Piglets were individually weighed post-farrowing, 14 days prior to weaning and at weaning. The piglet rate of gain was calculated for each time period. The feed intake of the sows was recorded on a daily basis (individual for FC and PS treatments).

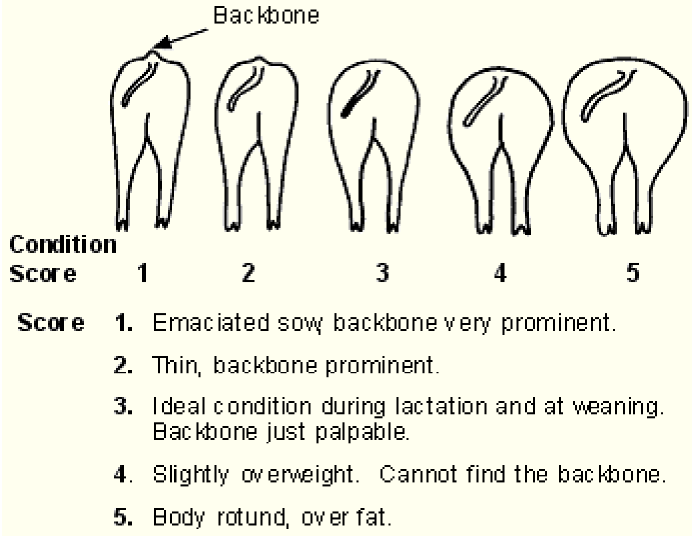

Figure 3 - Condition scoring system for gestating sows.

Sow injury scores

Sow injury scores were assessed on all sows prior to farrowing, 14 days prior to weaning, 13 days prior to weaning (the day after mixing in GL treatments) and at weaning. Each sow was individually assessed for skin lesions as described by Karlen *et al.* (2007). 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 for injury data collection. The number and the type of skin injuries were recorded, and, from these records, the number of both fresh and total injuries (fresh and old injuries) were collated for each sow on each observation day.

Thirty six sows per treatment were selected as focal animals for stress physiology and lactational oestrus measurements. This included all sows in the GL treatments.

Stress physiology

Saliva samples were collected from all focal sows in the group lactation housing treatments the day after mixing and 6 days prior to weaning. Saliva was collected by allowing the sows to chew on cotton buds that were attached to a plastic cable tie (Salivettes®, Sarstedt Australia, South Australia, Australia) for approximately 30s. All of the samples were collected between 13:00 and 14:00hrs to minimise diurnal variation. The technician entered the pen carrying a stock board and moved the focal sow quietly to the corner and encouraged her to chew on the cotton bud. The samples were centrifuged at 7000 rpm and stored at -20°C until analysed. Saliva samples were analysed for cortisol concentration using an RIA kit (MP Biomedicals Australasia | 2/29 Bearing Road, Seven Hills NSW). The sensitivity of the assay was 10 ng/mL. Mean intraassay CV for low (186 ng/mL) and high (444 ng/mL) saliva samples were 1.10% and 5.45%, respectively.

Aggression and suckling behaviour in group lactation system

Behaviour observations were conducted in the GL housing treatments. Each of the group lactation pens were recorded via video (using HD Sports cameras) that enabled view of the whole pen. The behaviour of the sows was recorded by a scan sampling technique (1 hour of continuous observation for aggression and 4 hours for suckling behaviour observations) the day of mixing into group lactation (immediately post-mixing), 7 days post-mixing (from 0800hrs) and the day before weaning (from 0800hrs). The frequency of aggressive interactions between sows, the latency to first suckling post-mix, frequency of disturbed sucklings, synchrony of behaviours (i.e. co-ordinated milk let-downs) and the extent of cross-suckling (percentage of own litter being suckled) was observed during these time periods.

The following ethogram was used to describe behaviours.

Table 1 - Ethogram of behaviours classified as aggressive[1] adapted from Hemsworth et al (2013) and sexual behaviour (adapted by Rault *et al.*, 2014).

Aggressive 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 performer's 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.

[1]A bout criterion interval of 5 sec was used. An interruption of more than 5 s was considered a new bout.

Sexual Behaviour - Initiator	Description
Flank nosing	Repeated contact with the flat tip of the nose to the flank area of another sow, where 'contact' is the snout touching or appearing to touch, i.e. within 5 cm of the flank and 'repeated' is 2 or more sequential contacts or head movements.
Ano-genital sniffing	Flat tip of the snout of the sow is: orientated towards; at the same height; and within 1 head distance of the vulva of another sow.
Mount	2 legs on the back of another sow
Attempt to mount	The initiator is standing with the head or 1 leg on the back of another sow
Unsuccessful mount	Slipped on the floor, or attempt to mount bout < 2 s
Behaviour - Receiver	
Standing posture	Immobile and stand upright for > 5 s, immobile stance, arched back and cocked ears
Flee	Movement of two steps or more by the receiving sow away from the initiator to another location in the pen
Aggressive	Bite, knock, push
No reaction	No obvious behavioral reaction to the initiator

[1] Each behaviour was scored using a bout criterion interval of 5 sec. An interruption of more than 5 s was considered a new bout.

Reproductive performance and piglet mortality

The number of piglets born alive, stillborn and mummified were recorded for each farrowing system. The date and cause of death of piglets from birth to weaning was recorded on a daily basis.

Lactational Oestrus

A sow was defined as showing signs of lactational oestrus if a number of criteria were met that collaborated with that of oestrus occurrence during lactation or up to 3 days after weaning. The criteria included sow sexual behaviour (only in group lactation pens), monitoring of follicle growth and size at 7 days prior to weaning and at weaning and progesterone concentrations four days post weaning that would indicate active corpora lutea on the ovary suggesting the sow had ovulated in the previous 15 days. Any display of oestrus after 3 days post-weaning was defined as a weaning induced oestrus.

Sexual behaviour observations

Each of the group lactation pens were recorded via video from mixing until weaning using mounted cameras (Signet Model QV-3063) that enabled views of the whole pen. Signs of sexual behaviour were recorded and as described in the Ethogram in Table 1.

Post-weaning to remating interval

The weaning-to-remate interval was defined as the number of days taken after weaning for the sow to shows signs of standing oestrus and then be successfully mated. Wean-to-remate intervals (WRI) > 3 days were indicative of the beginning of spontaneous lactational oestrus.

Rectal Ultrasound

Ovarian follicle development and size was measured 7 days prior to weaning and at weaning via rectal ultrasound using an ultrasonic device with a 10-6 Mhz convex probe (My Lab One Vet. Esaote Europe B.V., Maastricht, the Netherlands). Follicles larger than ≥ 4mm were classified as large (Quesnel and Prunier, 1995) and were indicative of growing follicles. Follicles < 4mm at weaning, in conjunction with elevated progesterone concentration and extended WRI, was considered suggestive of lactational oestrus and ovulation.

Blood sampling and progesterone concentration

Four days after weaning a blood sample was collected from each focal sow at approximately 1300hrs. The sows were snared and the blood sample was collected within 2 min of restraint. Each 2 mL blood sample was collected in lithium heparin tubes (10mL lithium-heparinized tubes; BD Vacutainer) and subsequently stored on ice before being centrifuged for 10 min at 1,912 × g at 4°C and transferred to microtubes for long-term storage at -20°C.

Plasma progesterone was determined by Enzyme Linked Immunosorbent Assay (ELISA) by the principle of competitive binding in 25 mL of plasma, according to the manufacturer's instructions (Demeditec Diagnostics GmbH, Kiel-Wellsee, Germany). The precision of the kit was as follows - intra-assay CV was <10%, the inter-assay CV was 9.96% at 0.56 ng/mL, 4.34% at 4.55ng/mL and 5.59% at 10.65 ng/mL. The analytical sensitivity of the kit was 0.045 ng/mL.

Statistical analysis

Reproductive performance, mortality, stress physiology and growth.

All data were checked for normality and homogeneity of variance, and transformations applied as necessary (logarithmic). Statistical analyses were performed using SPSS

(Version 21 -SPSS Inc., Chicago, Illinois, USA). Analysis was conducted using Univariate General Linear Model, using each sow/litter as the experimental unit (housing at start of experiment) and replicate as a fixed factor. Chi-squared analysis was used to determine if there were differences between cause of piglet death and number of sows removed due to death, illness and agalactia.

Lactational oestrus and behaviour

After the descriptive statistics all data were first checked for a normal distribution (KS-test P-value>0.20) and if a non-normal distribution existed the data were transformed on a log scale to obtain a normal distribution and afterwards back transformed before reporting the results. An ANOVA test with a post hoc Bonferroni test was used to compare the continuous data between the four groups. An independent two-sided T-test was used for analysis of variation of video data. The program PASW® Statistics 18 (SPSS, Inc, Chicago IL, USA) was used to process the data.

3. Results

Table 2 - Number of sow removals in the FC, GL_{FC}, PS and GL_{PS} housing treatments.

	Crate	Crate → Group lactation	PigSAFE	PigSAFE → Group lactation
Required to be foster sow	2	0	0	0
Not pregnant	1	0	1	0
Agalactia	1	0	0	0
Leg problems/lameness	2	0	1	0
Total number of sows	144	36	144	36

Table 2 shows the number of sow removals in each of the housing treatments. There was no significant difference (P>0.05; χ^2=2.3) in the number of removals due to health problems (i.e. agalactia, leg problems, downer sows).

Table 3 - Sow characteristics in the FC, GLFC, PS and GLPS housing treatments.

	Crate	Crate → Group lactation	PigSAFE	PigSAFE → Group lactation	SEM	P value
Average sow parity (range gilt=0 to parity 5)	2.3	2.2	2.2	2.2	-	-
Sow body condition score (Entry)	3.5	3.4	3.4	3.4	0.03	0.457
Sow body condition score (Weaning)	3.3	3.3	3.1	3.2	0.03	0.141
Sow P2 Backfat (mm) (Entry)	25.3	24.6	24.5	24.7	0.27	0.501
Sow P2 Backfat (mm) (Weaning)	22.3	22.5	22.0	22.5	0.26	0.892
Sow liveweight (kg) (Entry)*	282.0	285.1	280.2	287.4	2.31	0.791
Sow liveweight (kg) (Weaning)	252.7	256.4	248.03	259.6	2.26	0.388
Sow liveweight (kg) (Change between pre-farrow and wean)	-29.5	-28.6	-33.7	-27.8	1.19	0.216
Sow feed intake (kg/day)	7.04[a]	-	7.78[b]	-	0.11	0.000

*Sow weight at start includes weight of conceptus.

[abc] Within rows values with different superscripts are significantly different (P<0.05).

Table 3 shows the sow characteristics in each of the housing treatments. There was no significant difference (P>0.05) in the sow body condition score, backfat levels or liveweight change in each housing treatment. Sows in the PS system had a significantly higher (P<0.05) feed intake during lactation compared to sows in the FC system. The feed intake of sows in the group lactation treatments was not measured as it was not able to be recorded accurately compared to individual recording in FC and PS treatments.

Table 4 - Sow reproductive performance, piglet survival and piglet growth in the FC, GL_{FC}, PS and GL_{PS} housing treatments.

	Crate	Crate → Group lactation	PigSAFE	PigSAFE → Group lactation	SEM	P value
Litters farrowed	141	36	142	36	-	-
Litter characteristics						
Average number of piglets born alive[¥]	11.7	-	11.6	-	0.14	0.902
Average number of still born piglets[¥]	0.79	-	0.83	-	0.06	0.774
Average number piglets weaned*[€]	9.2	9.7	9.2	8.9	0.10	0.385
Live born mortality (%)*	16.6	14.6	19.9	20.3	0.82	0.094
Piglet growth						
Average piglet birth weight (kg)[¥]	1.70	-	1.72	-	0.006	0.150
Average piglet weaning weight (kg)**	7.04[a]	6.71[b]	7.12[a]	6.79[b]	1.88	0.000
Piglet rate of gain (g/day-birth to wean)**	217[a]	193[b]	220[a]	201[b]	0.07	0.000
Piglet rate of gain (g/day-mix to weaning)**	258[a]	167[b]	246[a]	179[b]	0.01	0.000
Coefficient of variation (%) -14 days prior to weaning	22.5	21.7	21.8	20.1	0.362	0.38
Coefficient of variation (%) at weaning	21.4	19.7	21.1	20.8	0.652	0.38

*Number of piglets born alive used as covariate in analysis. Liveborn mortality figures are calculated for each litter (taking into account fostering adjustment)-these figures do not reconcile with average numbers born and weaned.

**Piglet birth weight used as covariate in analysis.

[¥] Data pooled for FC and PS treatment as housing treatment was the same at this time

[€] Includes fostered piglets

[ab] Within rows values with different superscripts are significantly different (P<0.05).

Table 4 shows the sow reproductive performance, piglet survival and piglet growth in the FC, GL_{FC}, PS and GL_{PS} housing treatments. There was no significant difference (P>0.05) between treatments in average number of piglets born alive, number of stillborn piglets and number of piglets weaned. There was a trend (P<0.1) for liveborn mortality to be higher in the PS and GL_{PS} treatments. There was no interaction between housing treatment and replicate in liveborn mortality. Piglets in the GL_{FC} and GL_{PS} treatment had a significantly lower (P<0.05) rate of gain than piglets in the FC and PS treatments. There was a trend (P<0.1) for piglets in the GL_{PS} treatment to have a higher rate of gain than their counterparts in the GL_{FC} treatment whilst they were in the group lactation system. There was no significant difference (P<0.05) in the coefficient of variation prior to mixing or at weaning in piglet growth between all housing treatments.

Figure 4 shows the percentage of total piglet deaths (live born deaths) relative to the days of age of the piglet. Over the whole farrowing and lactation period, there was no significant difference (P<0.05) in live born mortality between housing treatments, however there was a higher percentage ($P<0.05$; $\chi^2=19.38$) of piglets that died post-mixing into the group lactation treatments compared to those that remained in the FC and PS treatments. This increase is seen in Figure 4 by the spikes in piglet mortality after day 14 (after piglets mixed into group lactation). The majority of piglet deaths in all housing treatments occurred in the first 2 days post-birth.

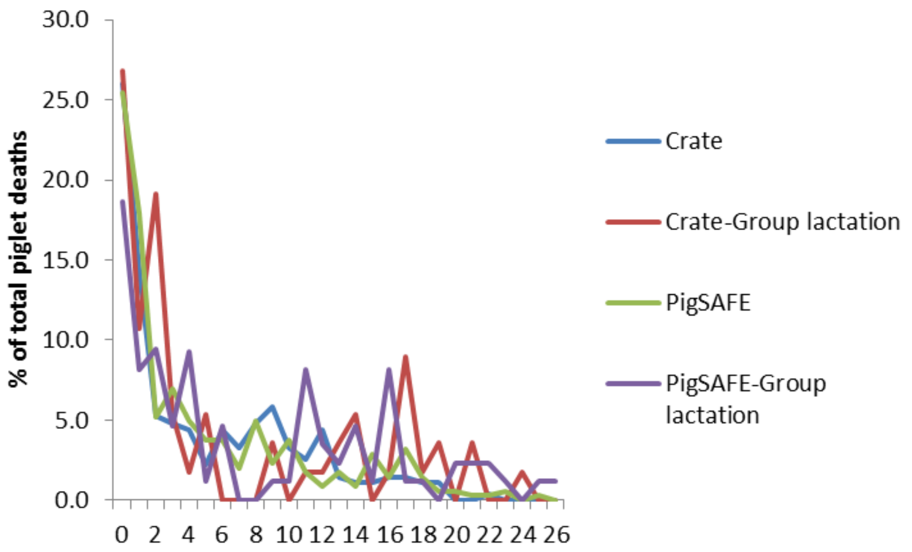

Figure 4 - The percentage of total piglet deaths relative to days of age of the piglet.

Figure 5 shows the cause of death each housing treatment. The majority of deaths were due to piglets being overlain by the sow. There was no significant difference ($P>0.05$; $\chi^2 = 5.7$) in the percentage of overlain pigs between housing treatments between birth and weaning.

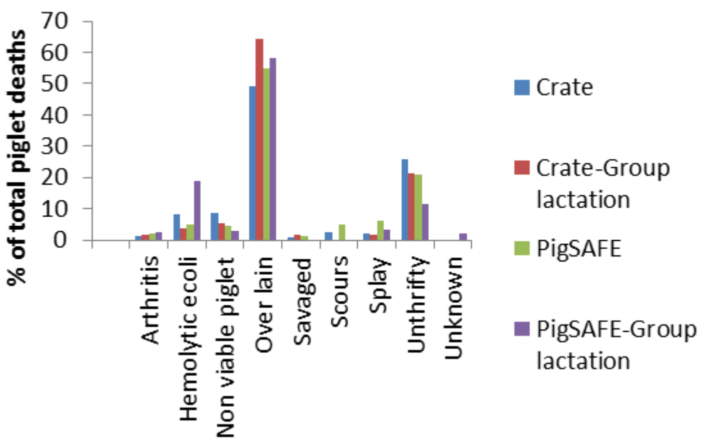

Figure 5 - The cause of piglet death in FC, GL_{FC}, PS and GL_{PS} (percentage of total piglet deaths) from birth to weaning.

Figure 6 shows the main cause of death of piglets during 14 days post-weaning to weaning (during the group lactation period). There was no significant difference in the number of overlain piglets in the FC and GL treatments during this period, however there was a lower percentage of overlain pigs in the PS treatment during this time ($\chi^2=28.85$; P=0.000). There was a significantly higher ($P<0.05$) percentage of piglets that died due to being unthrifty in the GL treatments ($\chi^2=32.41$; P=0.000) compared to the FC and PS treatments.

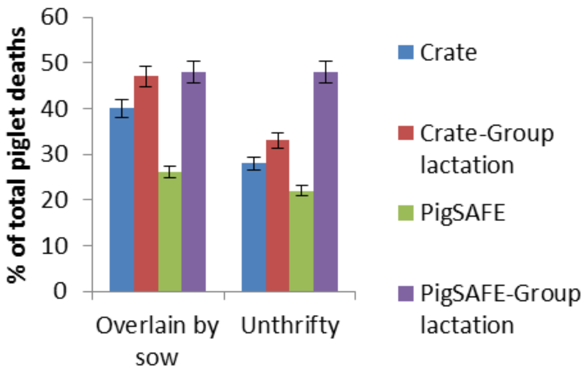

Figure 6 - The main cause of death from 14 days prior to weaning to weaning (i.e. during group lactation period).

Table 5 - Sow salivary cortisol, injury scores and aggression in the FC, GL_{FC}, PS and GL_{PS} housing treatments.

	Crate	Crate → Group lactation	PigSAFE	PigSAFE → Group lactation	SEM	P value
Cortisol (ug/ml) : Post-mixing in group lactation.	-	39.0	-	31.9	1.8	0.064
Cortisol (ug/ml): 6 days prior to weaning in group lactation.	-	73.3	-	67.8	5.82	0.66
Fresh injuries*						
Prior to entry to farrowing treatment	0.84 (6.9)	0.67 (4.7)	0.61 (4.1)	0.59 (3.9)	0.03	0.452
14 days prior to weaning**	0.45 (2.8)	0.68 (4.8)	0.35 (2.2)	0.22 (1.7)	0.03	0.071
13 days prior to weaning**	0.20^{a} (1.6)	1.04^{c} (11.0)	0.26^{a} (1.81)	0.68^{b} (4.8)	0.03	0.000
Weaning	0.35 (2.2)	0.26 (1.8)	0.39 (2.5)	0.31 (2.0)	0.02	0.862
Sow aggression (no. of 5 sec bouts)						
Post mixing in group lactation	-	32	-	19	-	0.61
7 days post-mixing	-	2	-	2	-	1.00
Weaning	-	0	-	0	-	1.00

*Transformed means are presented and back transformed means presented in parenthesis.

** 14 days prior to weaning is the day before mixing into group lactation in GL_{FC} and GL_{PS} and 13 days prior to weaning is the day after mixing into group lactation in GL_{FC} and GL_{PS}

[abc] Within rows values with different superscripts are significantly different (P<0.05).

Table 5 shows the sow salivary cortisol concentrations (group lactation treatments), sow injury scores and incidence of aggressive behaviour in the housing treatments. Sows in the GL_{FC} treatment had a strong trend for significantly higher cortisol (P=0.064) than GL_{PS} post-mixing into group lactation, however there was no significant difference (P>0.05) at weaning. There was no significant difference (P>0.05) in the number of fresh injuries between housing treatments prior to entry to housing treatment or at day 14 prior to weaning (before mixing into group lactation treatments). On day 13 prior to weaning (the day after mixing into group lactation) sows in the group lactation housing treatments had a significantly higher (P<0.05) number of fresh injuries compared to FC and PS treatments and the GL_{FC} treatment had higher (P<0.05) number of fresh injuries compared to GL_{PS}.

There was no significant difference (P>0.05) in observed aggression post-mixing, seven days post-mixing or at weaning.

Table 6 - Sow maternal behaviour in GL_{FC} and GL_{PS} housing treatments.

	Crate → Group lactation	PigSAFE → Group lactation	P value
Time to first suckle post-mixing (minutes)	52:26[a]	35:00[b]	0.048
% of own litter suckled			
Post-mixing (%)	55.8 ± 27.2	44.3 ± 18.8	0.06
Day 7 (%)	58.9 ± 21.8	48.3 ± 16.4	0.01
Weaning (%)	45.7 ± 17.7	54.2 ± 16.5	0.04
Ave. number of interrupted sucklings			
Post mixing	0.1	0.2	1.00
Day 7	0.0	0.0	1.00
Weaning	0.1	0.0	1.00

[abc] Within rows values with different superscripts are significantly different (P<0.05).

Table 6 shows the maternal behaviour of the sow in the group lactation housing treatments. Sows in the GL_{PS} had significantly shorter (P<0.05) time to first suckle post-mixing into group lactation compared to GL_{FC}. There was a significant difference (P<0.05) in the percentage of own litter suckled between the housing treatments over the observation periods, however on average sows suckled 50% of their own litter in both treatments over the lactation period. There was an extremely low incidence of interrupted suckling during the observation period with no significant differences (P>0.05) between treatments. Anecdotal evidence suggests that sows suckled simultaneously throughout lactation.

Table 7 - Lactational oestrus in the FC, GL_{FC}, PS and GL_{PS} housing treatments.

	Crate	Crate → Group lactation	PigSAFE	PigSAFE → Group lactation	P value
Ave. parity for sample	2.3 ± 1.6	2.2 ± 1.5	2.2 ± 1.5	2.2 ± 1.5	0.997
Ave. WRI (days)	5.2 ± 3.2	8.3 ± 6.6	7.4 ± 6.1	7.6 ± 6.5	0.155
Sows with WRI ≤4 days (%)	75[a]	56.3[b]	53.1[b]	45.5[b]	0.049
Sows with WRI 5-7 days (%)	15.6	12.5	25	15.2	0.294
Sows with WRI >7 days (%)	9.4	31.3	21.9	27.3	0.804
Sows with WRI ≥21 days (%)	0	9.4	6.3	6.1	0.413
Sows mated after weaning (%)	88.9	88.9	91.4	91.7	0.706
Ave. no. of piglets born alive in subsequent litter	12.09 ± 3.1	11.95 ± 2.8	12.78 ± 2.4	11.38 ± 1.5	0.441
Sows with large follicles 7 days after mixing (%)	5.5[b]	36.1[a]	8.6[b]	19.4[a]	0.042
Sows with large follicles at weaning (%)	16.7[b]	11.1[b]	22.9[a]	11.1[b]	0.046

Sows with large follicles during lactation and Progesterone concentration >2.5/ml post- weaning (%)	15.2^{a} (n=33)	22.9^{b} (n=35)	25^{b} (n=32)	29.0^{b} (n=31)	0.045
Ave. WRI when Progesterone concentration >2.5ng/ml (days)	10.6^{a} (n=5)	14.3^{b} (n=6)	15^{b} (n=7)	16.9^{b} (n=7)	0.080
Ave WRI for sows that presented large follicles during lactation (days)	5.8^{b} (n=5)	14^{a} (n=3)	8^{b} (n=8)	12.4^{a} (n=5)	0.047

WRI refers to the weaning-to-remate interval after weaning.

^ Large follicles are defined as any follicle measuring ≥ 4mm (Quesnel and Prunier, 1995).

^{ab} Within rows values with different superscripts are significantly different (P<0.05).

Table 7 shows that sows in the FC treatment had a significantly higher percentage of the treatment group with a WRI ≤4 days (P<0.05) compared to GL_{FC}, PS and GL_{PS} treatment groups. There was no significant difference in mating rates across all treatments (P>0.05). Subsequent farrowing records demonstrate that there was no significant difference in the total number of born alive piglets between treatment groups, where FC, GL_{FC}, PS and GL_{PS} treatments farrowed an average of 12.09, 11.95, 12.78 and 11.38 born alive piglets, respectively. Sows from PS, GL_{FC}, and GL_{PS} treatment groups had a significantly higher number of sows show signs of ovarian follicular growth during lactation compared to FC treatment sows (P<0.05).

Table 8: Lactational oestrus behaviour of GL_{FC} and GL_{PS} housing treatments. Data pooled for all observation periods.

	Crate-Group Lactation	PigSAFE-Group Lactation	P value
Initiator*			
Total no. of nosing's to the flank area	3	0	0.091
Total no. of successful mountings	0	0	1.00
Total no. of attempted mountings	4	2	0.455
Total no. of unsuccessful mountings	2	3	0.593
Total no. of ano-genital sniffings	36	37	0.270
Receiver#			
Total no. of sows that stood for the initiators behaviour	5	1	0.111
Total no. of sows that moved away/fled from the initiators behaviour	10	9	0.933
Total no. of sows that did not respond to the initiators behaviour	29	31	0.333

*Initiator refers to the sow within the group lactation system showing signs of oestrus behaviour.

#Receiver refers to the sows in group lactation that were in receivership of oestrus behaviour from an initiator sow.

Table 8 shows that there is no significant difference in the incidence of lactational oestrus behavioural signs performed by the initiator nor responses of the receiver sow, across both GL_{FC} and GL_{PS} treatment groups (P>0.05).

4. Discussion

Sow removal and lactation performance

There was no difference in the number of sows removed due to death, euthanasia, agalactia, injury or lameness. There was no difference in the body condition score and live weight change between entry and weaning between any of the housing treatments. Sows in the PS treatment had a higher feed intake compared to the FC treatments. This was also observed by Morrison and Cronin (2012) and it is speculated that the sows in the PS housing system have a greater area to move around and exercise which may influence their metabolic demand. The feed intake was not measured in the group lactation treatments as it was difficult to measure accurately compared to the individual intakes measured in the FC and PS treatments. Factors such as feed space requirements from *ad libitum* feeders are important as space to avoid higher ranking sows may be critical to limit stress and aggression. Further research is required to assess feed intake and performance of sows in group lactation housing systems

Piglet survival and growth performance

The number of piglets born alive, number of stillborn piglets, piglet survival (live born mortality) and number of piglets weaned per sow in the FC, GL_{FC}, PS and GL_{PS} systems were comparable over autumn and winter months under Australian conditions. There was no interaction between housing treatment and replicate (season) in which the experiment was conducted. There was a trend for higher piglet deaths in the PS and GL_{PS} housing treatment which supports the need for further development of these loose farrowing systems under Australian conditions. The majority of piglet deaths in all housing systems occurred within the first two days post-partum. These results are similar to other studies investigating piglet survival in loose and farrowing crate systems. The majority of piglets that die pre-weaning die within the first day postpartum (Marchant *et al.*, 2000), mainly because of crushing and starvation (Dyck and Swierstra, 1987; Pedersen *et al.*, 2006). In the current experiment the majority of piglet deaths in both systems were caused by being overlain by the sow. There was no significant difference in the number of overlain pigs in the group lactation system, however a higher percentage of piglet deaths during that time was attributed to being unthrifty.

The addition of straw is an essential component of the PigSAFE farrowing system. Evidence in the literature suggests that straw provides both behavioural and nutritional benefits for the sow and sows that do not have access to straw have greater heart rate (Damm et al., 2003), greater concentrations of cortisol before farrowing (Lawrence et al., 1994), longer duration of parturition, resulting in more still birth piglets (Cronin et al., 1993), shorter nursing duration (Herskin et al., 1999), and more postural changes the first 24 h postpartum (Herskin et al., 1998). Based on this empirical evidence, recent European Union legislation requires that sows must be given “suitable nesting material in sufficient quantity unless it is not technically feasible for the slurry system used in the establishment” (Council of the European Union, 2001). In the current experiment there was no significant difference in the number of still born piglets between housing treatments and there were no significant parity effects due to housing treatment. Anecdotal evidence suggests that sows utilised straw in the PigSAFE housing treatments and the current design of the PigSAFE systems met the ‘biological needs’ of the sow and piglet as described by Baxter *et al.* (2011a,b). The sows had room to move around to allow for increased activity associated with nest building, substrate was provided for nest building which the sows utilized, solid walls of the pen allowed the sow to isolate herself and the sow was not confined at any time.

The growth rate of piglets in the FC and PS housing treatments was similar. However, mixing piglets into group lactation resulted in reduced piglet growth rate and lower weaning weight. This growth check of piglets in group lactation has been observed by others (see review by Van Nieuwamerongen *et al.*, 2014) and may be attributed to increased activity, social interactions and/or cross suckling which was observed in this experiment (sows in the group lactation treatment suckled on average 50% of their own litter) or perhaps a reduction in sow feed intake in the group lactation pens (which was unable to be measured this experiment). Van Nieuwamerongen *et al.* (2014) state that the effect of cross-suckling on piglet performance is not straight forward. Some authors have reported reduced piglet growth rate, whilst others have reported greater piglet uniformity and performance. The coefficient of variation of piglet liveweight was similar between treatments prior to mixing into group lactation and at weaning, which indicates that the spread in variation in liveweight did not increase as a result of group lactation housing. The cause of reduced growth rate of piglets in group lactation requires further investigation.

There was a trend for piglets in the GL_{PS} treatment to have higher growth rate than piglets from GL_{FC} treatment. This difference may be associated with piglets being familiar prior to mixing (i.e. fenceline contact through PigSAFE pens) and may have had the opportunity to socialize prior to mixing. There may be additional benefits, as integrating sows and piglets before weaning has been shown to reduce some factors associated with weaning stress; e.g. early socialisation of piglets reduces aggression at weaning (D'Eath, 2005) and piglets raised in group lactation may have improved social development resulting in less aggression when mixed at weaning (Verdon, 2013-unpublished-Appendix 1). Van Nieuwamerongen *et al.* (2014) state that the post-weaning growth check observed in piglets from conventional housing may be reduced in piglets from group lactation systems as piglets may be better adapted to the weaning environment i.e. improved social skills and development and increased experience with solid food. The potential issues (and possibly strengths) of group lactation requires further research.

Sow welfare

In this experiment the biological responses of the sow were used to assess sow welfare. The stress response commences when the central nervous system first perceives a potential challenge (stressor) to homeostasis and one of the key biological defence responses is that of the neuroendocrine system with the activation of the hypothalamic-pituitary-adrenal (HPA) axis and the release of corticosteroids (Barnett and Hemsworth, 2009). Therefore cortisol concentrations were measured in this experiment to determine activation of the HPA axis. Behavioural observations and skin injuries were assessed in the group lactation treatments to study aggression (Karlen *et al.*, 2007).

Sows in the GL_{FC} had a higher stress response and more fresh injuries than sows from GL_{PS} after mixing into the group lactation pen. Interestingly, even though there were more fresh injuries (resulting from aggression) in the GL_{FC} treatment compared to the GL_{PS} treatment, there was no difference in aggression during the one hour observation period. It is speculated that these injuries resulted from aggression during time periods outside the observation period post-mixing. The effects of socialization and familiarisation through fenceline contact in PigSAFE system appears to be beneficial when sows are mixed into group lactation. This effect appeared to diminish by weaning as there was no treatment difference in aggression, stress response or injuries by that time, indicating that sows had settled down over time.

Lactational oestrus

The weaning-to-remate interval is typically characterised as an unproductive phase of the breeding cycle and can have negative effects on the overall performance of the animal (Vorgin-Bracic and Skorjanc, 2008), in particular the number of piglets produced/sow/year. The current experiment resulted in upwards of 88% subsequent mating rate across all treatment groups. This result is comparable to the current industry target of 85%. Previous studies show that 15% of conventionally housed sows, weaned around 29 days after farrowing, experience lactational oestrus and ovulation (Downing *et al.*, 2012). Naturally occurring lactational oestrus was also observed in this experiment, where only 15% of sows from the FC treatment group presented with large follicles during lactation and also had recorded progesterone concentrations of > 2.5ng/mL four days post-weaning. There are a combination of factors that contribute to this result, including litter size, seasonal temperatures, photoperiod, health status and stress. A higher numbers of sows from the FC treatment group returned to oestrus within 4 days post-weaning, compared to their loose/group housed counterparts, indicating they had not had lactational oestrus.

Those sows recorded as having an extended weaning-to-remate interval (10-19 days) were assumed to have experienced spontaneous oestrus and ovulation during lactation. This was confirmed in some sows via rectal ultra-sounding 7 days prior to weaning and on the day of weaning, in order to monitor ovarian follicular growth. The incidence of ovulation was confirmed via plasma progesterone concentrations four days post-weaning. Progesterone concentration typically remains low during lactation with the absence of an active corpus lutea (Quesnel and Prunier, 1995). However, during lactational oestrus progesterone concentration begins to rise around 30h after the pre-ovulatory luteinizing hormone surge (Shaw and Foxcroft, 1985). Hence, sows that have experienced an active lactational oestrus and subsequent ovulation should normally have a plasma progesterone concentration of greater than 2.5ng/mL 4 days post-weaning compared to the mean plasma progesterone concentration normally seen during the weaning to oestrus interval between 0.14-0.78ng/ml (Shaw and Foxcroft, 1985).

Approximately, 23, 25 and 29% of sows in the GL_{FC}, PS and GL_{PS} treatment groups presented with large follicles during lactation and progesterone levels greater than 2.5ng/mL post weaning (indicative of ovulation), compared to only 15.2% of sows housed in farrowing crates for the duration of lactation. Furthermore, sows in PS and GL_{FC} and GL_{PS} that had progesterone concentrations higher than 2.5ng/mL post weaning also had an average weaning-to-remate interval greater than 14 days compared to an average of 10.6 days for the FC treatment. Not only does this support the theory of spontaneous oestrus but also suggests that those sows in loose and group housing systems experience a spontaneous lactational oestrus earlier than sows in a conventional farrowing crate system. This could be attributed to a change in suckling frequency and intensity, as well as changes in neuroendocrine reflexes associated with extended lactation and changes in environment. Subsequent reproductive performance across all treatment groups was promising, with the total number of piglets born alive averaging 11.4 through to 12.8. It appears that PS and GL housing may make sows more sensitive to oestrus during lactation.

Lactational oestrus occurred in the PS, GL_{FC} and GL_{PS} treatments, however not at the target required for commercial adoption (i.e. Pork CRC target is 85% incidence of lactational oestrus). It is speculated that lactational oestrus occurred in these treatments as they all involved some form of loose housing at some point during the lactation period. Sows housed in a loose or group lactation system have the opportunity to freely move around, enabling them to self-wean their piglets and regulate their nursing behaviour, slowing the stimulation and release of neuropeptides and hormones through the natural endocrine reflexes (Quesnel and Prunier, 1995). By inhibiting the feedback mechanism on the hypothalamus, the pituitary gland begins to initiate follicle stimulating hormone and luteinizing hormone production, stimulating the onset of oestrus and subsequent ovulation (Senger, 2003). Social interaction seen between sows within group lactation systems were observed in this experiment, particularly aggression and sexual behaviours such as flanking, ano-genital sniffing and mounting which could also stimulate the onset of oestrus. In addition, loose housing such as PigSAFE, and group lactation housing systems enable the free and unrestricted movement of both sows and piglets in a much larger area, enabling the sow the ability to control suckling freqency and intensity and to theinitiate gradual weaning of piglets later in lactation. Whereas, within a conventional crated lactation system, both sows and piglets have very limited ability to move away from one another in order to initiate self-weaning

Suckling behaviour

The results show that there was a high incidence of cross suckling within the group lactation system. Throughout the entirety of the group lactation period, both GL_{FC} and GL_{PS} sows suckled approximately 50% of their own and 50% of other sows piglets. Anecdotal evidence suggests that the majority of group housed sows participated in synchronised letdown whilst group housed. There were limited to no interrupted sucklings recorded across both treatment groups. This is important as it reduces aggression in both sows and piglets, promotes positive hormone feedback within the sow and enables piglets the best chance of optimal growth potential. Interestingly, sows from a the GL_{FC} treatment took a significantly longer time to first letdown after mixing in comparison to sows from the GL_{PS} treatment. This could be attributed to an increase in stress associated with mixing with unfamiliar animals. In comparison, sows that have been moved from the PigSAFE system and mixed into group lactation housing seemed to be less affected by the stress of mixing and letdown in considerably less time. This could perhaps be attributed to the design of the PigSAFE system which allows social interaction between sows of adjoining pens.

5. Conclusion/Recommendations

The 'two-stage' system has shown promise, as many of the performance parameters were similar to the farrowing crate system and PigSAFE loose farrowing system under Australian conditions between March and November. Piglet survival over the whole farrowing and lactation period (live born mortality), number of piglets weaned and sow performance was similar in all housing systems. However, piglet growth rate and weaning weight was reduced and there was a higher percentage of unthrifty pigs and an increase in piglet deaths post-mixing in the group lactation system, which may be attributed to cross suckling, increased socialisation and activity and perhaps lower feed intake of sows. Further research is required to assess piglet survival, long-term implications of this growth-check and piglet welfare in group lactation systems. Overall, there was a trend for higher piglet mortality in the PigSAFE system which supports the need for further development of these loose farrowing systems under Australian conditions. The majority of piglet deaths in all housing systems occurred within the first two days post-partum.

Sows moved from the PigSAFE in to group lactation system had less fresh injuries, and lower salivary cortisol the day after grouping and suckled their litter quicker than sows introduced to the group lactation pen from a farrowing crate 14 days prior to weaning. It is speculated that sows were familiar with each other (through the design of PigSAFE pen) and had more opportunity to bond with their piglets previously. There appear to be benefits of mixing familiar animals into group lactation systems.

Spontaneous lactational oestrus occurred in the all housing treatments. Approximately 9% of sows in farrowing crate treatment and 27% of sows in the PigSAFE and group lactation treatments experienced lactational oestrus. However, these levels are not commercially viable levels (i.e. a target of 85% incidence of lactational oestrus required in the herd before able to be adopted as a viable production system). It is speculated that the ability of the sow to naturally regulate nursing behaviour and wean piglets by avoidance in loose farrowing and group lactation environment may be implicated. If a 'two-step' system is further developed and lactational oestrus is viable to implement in such a system, then further research to induce lactational oestrus (i.e. piglet separation and boar exposure in group lactation) is required. On the other hand, if mating during lactation is not desired by the pork producer, then producers need to be aware of and manage extended wean-to -remate interval in a proportion of the sows and management strategies may need to be implemented to reduce the risks associated with sows showing signs of lactational oestrus in loose farrowing and lactation systems.

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Appendix 1

The effects of group lactation sow housing on aggression and injuries in weaner pigs.

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We hypothesised that raising pigs in group-housed sow lactation systems will reduce aggression and injuries following mixing at weaning, in comparison to piglets raised in non-group lactation systems. Four treatments were applied to 72 sows and their litters (n=642 piglets) over two replicates. These were (1) Farrowing crate (FC; n=24 sows), (2) PigSAFE (PS; n=24 sows), (3) Farrowing crate and group lactation (GL_{FC}; n=12 sows), and (4) PigSAFE and group lactation (GL_{PS}; n=12 sows). FC and PS pigs remained in that environment from birth until weaning. GL_{FC} and GL_{PS} pigs were housed in FC and PS environments, respectively, from birth until 14 d of age after which they were transferred (with their dams) to group lactation pens (n=6 sows and litters/pen), where they remained until weaning. After weaning at 27 d pigs were mixed into pens of four litters from the same treatment and behaviour recorded for 2 h. The average group size and stocking density at mixing was 35.7 pigs and 0.54 m^2/pig. The following were calculated for each litter: frequency non-reciprocal aggression, fights (frequency, total duration, average duration, time to start fighting) and total aggression (fights + non-reciprocal aggression). Further, six pigs from each litter were randomly selected for skin lesion scoring on the day prior to weaning and 24 h post-mixing, so that lesions sustained at mixing could be calculated. Data were transformed where appropriate. Treatment effects were examined using a two-tailed univariate ANCOVA with replicate included in the model as a blocking factor. Group size and litter weight at mixing were deemed to be suitable covariates. Multiple comparisons were performed using the LSD test. GL_{FC} and GL_{PS} pigs sustained fewer skin lesions ($P<0.01$), delivered less non-reciprocal aggression ($P<0.01$), took longer to start fighting ($P=0.04$), fought less frequently ($P=0.01$) and engaged is less total aggression ($P<0.01$) than either FC or PS pigs. Further, GL_{FC}, GL_{PS} and PS pigs spent less total time fighting ($P=0.01$) than FC pigs, although treatment had no effect on average fight duration ($P>0.05$). Learning through social interaction is likely the major means by which immature animals acquire social skills. Experience of social aggression modulates aggressive behaviour as prior winning experiences raise, and losing experiences lower, an individual's perceived fighting ability without altering actual fighting ability (Hsu, Early & Wolf. Bio. Rev. 81:33, 2006). These results emphasise the role of social experience in the development and regulation of aggression in the pig.