REDUCING THE CONFINEMENT OF PERI-PARTURIENT AND LACTATING SOWS
PROJECT 1A 110

Prepared for the
Co-operative Research Centre for High Integrity Australian Pork

By

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Executive Summary

Farrowing crates were developed initially to reduce piglet mortalities (primarily due to sow crushing), improve access to piglets for routine husbandry, reduce labour inputs and help address worker safety issues. However, confinement in farrowing crates is thought to negatively impact on sow welfare and, therefore, there is an increased need to understand what options are available to producers to allow sow confinement to be reduced during lactation. The aim of this study was to determine how, under commercial conditions and across summer and winter, different periods of reduced confinement during and after parturition affected sow and piglet performance as well as sow welfare.

This study was conducted at Sunpork farms south, using 608 sows (parity 3.3 ± 0.08; range: 1 – 9) in summer (sows farrowing between 21 January and 14 April 2016) and winter (sows farrowing 26th May to 30 August 2016). Within season, we allocated sows to one of five housing treatments.

1. CRATE ALL: sows farrowed and remained in a conventional farrowing crate (n = 145)
2. CRATE/PEN: sows farrowed in a conventional farrowing crate and then moved to a free movement pen on day 7 of lactation until weaning (n = 121)
3. SWING SHUT D-1to7: sows farrowed in a swing-sided crate, with sides opened until the onset of farrowing or the night before the sows due date and opened on day 7 post-farrowing (n = 118)
4. SWING SHUT to D7: sows farrowed in a swing sided crate with the sides shut from entry until day 7 post-farrowing (n = 112)
5. SWING OPEN ALL: sows farrowed in a swing sided crate with the sides open from shed entry until weaning (n = 112)

The following measures were collected: litter size (total born, born alive, stillborn), piglet mortality within 24 hours of farrowing, between days 1 and 3 post-farrowing, and between day 3 and weaning. Piglet weights on day 6 post-partum and the day prior to weaning. Sow weight and P2 backfat change as well as subsequent reproduction was also recorded. Individual treatment effects, and the effect of housing during farrowing were analysed using Genstat (version 15; VSN International Ltd., Hemel Hempstead, UK), using an ANOVA, with parity and total born included in the model. Cortisol was measured in plasma samples obtained from 30 sows / treatment / season on days 1, 4, 8 and 22 post-partum. Unless otherwise specified data are presented as Mean ± SEM, with significance accepted at $P < 0.05$, and tendencies at $P < 0.1$.

Overall, the current data demonstrated that allowing sows to farrow free (in an open swing-sided pen), did not decrease stillbirths and effectively doubled the number of live born piglets dying in the first 24 hours. The following is also clear from this study. One, piglet mortalities were approximately 3.5 times higher when sows and litters were housed in an open pen as opposed to closed pen or farrowing crate up until day 7 of lactation. Two, removing sow confinement from day 7 of lactation to weaning (either by opening the swing pen or moving the sow and litter to a simple pen) did not increase piglet mortalities when compared to crated sows during the equivalent time period. Importantly, these effects of housing were consistent across season. The relationship between sow housing and cortisol was less clear. Regardless of housing, cortisol levels were elevated on day 1 post-partum, compared to days 4, 8 and 22. Cortisol levels tended to be highest in sows which farrowed in conventional crates, with sows farrowing in open pens tending to have lower cortisol throughout lactation (regardless of day). In summary, the current data provide promising evidence that piglet mortalities and litter size and weight at weaning are not reduced when sow confinement is removed from day 7 of lactation onwards. However, it is also clear that housing sows in farrowing crates minimizes early piglet mortality rates, and does not

significantly increase cortisol levels. Further work should focus on enriching the environment of the farrowing crate to promote sow welfare. We also recommended the collection of additional data on the effects of reducing sow and litter confinement from commercial sites across Australia and from other non-confinement housing systems.

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1. Introduction

Negative public perception of sow confinement has resulted in the widespread eradication of dry sow stalls, and stimulated an increased need to understand what options are available to producers to reduce sow confinement during lactation. Farrowing crates were developed initially to reduce piglet mortalities (primarily due to sow crushing), improve access to piglets for routine husbandry, reduce labour inputs and help address worker safety issues. However, farrowing crate confinement is thought to negatively impact on sow welfare. Specifically, we know sows have an extremely strong, inherent drive to perform nest building behaviours, which cannot be fully expressed in a farrowing crate. Unfortunately, under commercial conditions the majority of piglet crushing occurs during the first 3 to 7 days post-partum, suggesting the major benefits of sow confinement in terms of piglet mortality will be achieved during this period. Based on natural behaviours it appears that sows are programmed to remain primarily sedentary, and in the 'nest', for 7 – 10 days post-partum, suggesting that confining sows during this period may have little effect on their welfare and capacity to express natural behaviours. However, this requires confirmation.

Previously, we compared the effect of different periods of sow confinement in a swing-sided crate (pen dimension of 2.4 x 2.4 m) and standard farrowing crate on the incidence of piglet mortality (Condous et al., 2016). Our results indicated that piglet mortality rates due to crushing (overlaying) are unacceptably high when sows are allowed to 'farrow free' and when confinement is reduced at day three of lactation. However, our data has demonstrated that the incidence of piglet crushing, and preweaning mortality are similar to conventional crates when sows are confined until day seven of lactation and then allowed freedom of movement by completely opening the sides of the farrowing pen. While we accept that allowing sows to farrow free, and perform natural behaviours, would be the ideal situation, the increased piglet mortalities from such a system is unacceptable for the welfare of the litter as well as the producer. As previously mentioned, sows appear to be programmed to remain primarily sedentary, and in the 'nest', for 7 – 10 days post-partum. Consequently, a management system, which reduces sow confinement to the 7 days following completion of nest-building behaviours, and maximises piglet and producer welfare by reducing piglet injury and deaths appears to be a viable compromise.

A recent body of work conducted in Denmark has also investigated the impact of different periods of sow confinement around parturition and during early lactation on piglet survival. Using a swing-sided crate / creep system with a similar footprint to a conventional crate/creep system (i.e. 1.8 x 2.6m), Moustsen et al. (2013) indicated higher incidences of piglet mortality in the first 24 hours post-partum in 2 out of the 3 treatments allowed to farrow free compared to the confinement farrow group. Further, these authors reported reduced piglet mortality for sows confined for the first 4 or 7 days post-partum and then the crate opened. In a subsequent trial, Hales et al. (2013) reported significantly higher incidences of piglet mortality both in the 24 hours post-farrowing and from day 1 of lactation to weaning in free farrowing pens compared to standard farrowing crates. Together, these data indicate that confinement of sows during farrowing and the first 4 – 7 days post-farrowing may be required if increases in piglet mortality are to be avoided. However, to our knowledge the effect of this confinement on sow behaviour, welfare and stress remains to be investigated.

The aim of this project was, therefore, to determine whether our recent evidence that, a marked reduction in sow confinement during lactation from 24 days to 7 days resulted in comparable piglet performance and survival under commercial conditions. The secondary aim of this project was to determine the effect of season (summer versus winter) on piglet performance and survival within the different housing systems.

2. Methodology

This study was conducted at Sunpork Farms South, using 608 sows (parity 3.3 ± 0.08; range: 1 – 9) in summer (sows farrowing between 21 January and 14 April 2016) and winter (sows farrowing 26th May to 30 August 2016). Within season, sows were allocated to one of five housing treatments.

6. CRATE ALL: sows farrowed and remained in a conventional farrowing crate (n = 145)
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Weaning took place 25.6 ± 0.17 (winter) and 25.9 ± 0.18 (summer) days after parturition, with the following measures collected for all sows and litters: litter size (total born, born alive, still born) and subsequent reproduction; piglet mortality within 24 hours of farrowing, between days 1 and 3 post-farrowing, and between day 3 and weaning. A subset of animals were used to collected the following measures (see Table 1 for number / measure / sample): piglet liveweight (LW) on day 6 post-partum and the day prior to weaning; sow LW and P2 backfat (P2) on day 2 and weaning; blood samples for cortisol analyses on days 4, 8 and 22 post-parturition

Table 1 Number of sows and litters per treatment and measurement

Treatment	Season	Total Sows	Plasma samples	Sow LW and P2	Piglet LW
CRATE ALL	Summer	72	30	42	28
	Winter	73	30	33	24
CRATE/PEN	Summer	61	30	34	17
	Winter	60	30	30	14
SWING SHUT D-1to7	Summer	55	30	30	21
	Winter	63	30	33	22
SWING SHUT to D7	Summer	53	30	31	19
	Winter	59	30	31	20
SWING OPEN ALL	Summer	55	30	31	20
	Winter	57	30	31	23

a)

b)

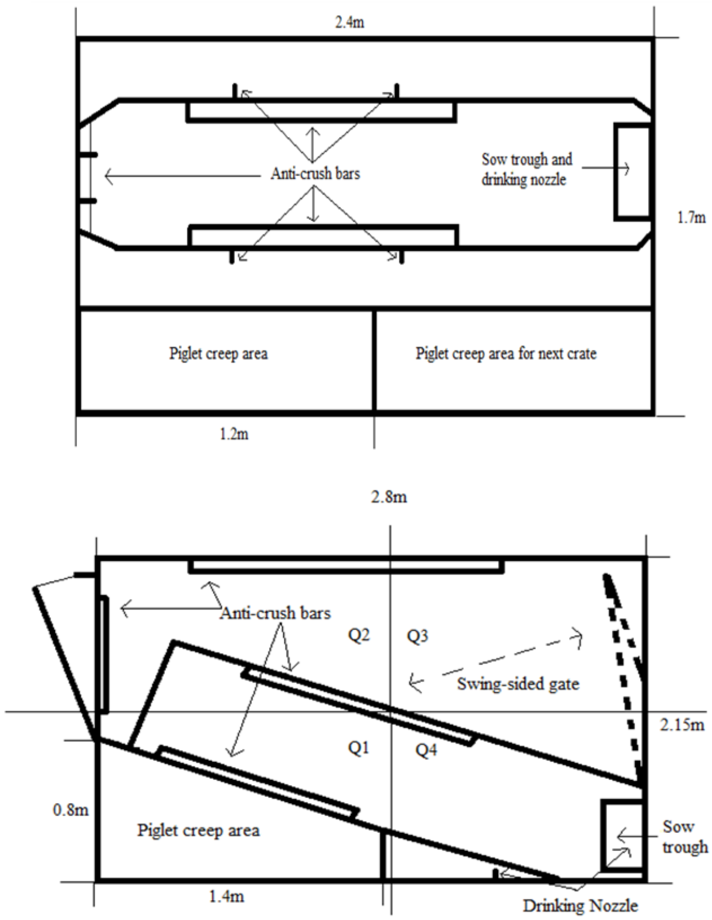

Figure 1. Diagram of the conventional farrowing crate (a) and the swing-side pen (b). Diagrams are not drawn to scale.

Blood plasma cortisol was determined at the Adelaide Research Assay Facility by coated tube radioimmunoassay (Immuchem 07221106; MPBiomedicals, Orangeburg, NY, USA) in duplicate. In brief, standards, samples or controls (25µl) and Cortisol ^{125}I tracer (1000µl) were added to supplied coated tubes and incubated for 45 minutes at 37°C, before the supernatant was discarded and the radioactivity bound to the coated tubes was determined by counting for 2 minutes in a Wizard 2470 gamma counter (Perkin Elmer, Glen Waverley, Victoria, Australia). The lower limit of quantitation (LLoQ) for the assay was 10ng/ml. The intra-assay coefficient of variation of the assays was 8.4%. The inter-assay coefficient of variation of the assays at the low quality control level (83ng/ml) was 14.3%. The inter-assay coefficient of variation of the assays at the medium quality control level (121ng/ml) was 12.6%. The inter-assay coefficient of variation of the assays at the high quality control level (551ng/ml) was 15.7%.

Statistical analyses were conducted using Genstat (version 15; VSN International Ltd., Hemel Hempstead, UK). Two separate analyses were conducted. One, the effects of housing during farrowing (Crate versus Open Pen versus Closed Pen) on piglet mortality to day 7 post-partum, and plasma cortisol levels were analysed using an ANOVA, with parity and total born included in the model. Two, the effects of individual treatments on all measures were also analysed using an ANOVA, with parity and total born included in the model. Litter weight the day prior to weaning was included in the model when analyzing treatment and season effects on sow weight and P2 and subsequent reproduction. Main effects of treatment and season of farrowing / lactation only are presented where interactions were not observed. Samples with a cortisol value below the detectible limit of the assay (10 ng / ml), were given a nominal value of 10 ng / ml. Treatment and season effects on percentage of sows mated, pregnant and farrowing were analysed using a chi-squared test. Unless otherwise specified data are presented as Mean ± SEM, with significance accepted at $P < 0.05$, and tendencies at $P < 0.1$.

3. Outcomes

Housing

Housing during parturition did not affect total litter size, the number of piglets born alive or the number of piglets born dead. However, it did affect piglet mortality (Table 2). Piglet mortalities during the first 24 hours post-partum were significantly lower for sows farrowing in crates versus closed or open swing pens, resulting in significantly lower total mortalities to day three post-partum and to weaning (Table 2). However, mortality rates between day 1 and 3 post-partum were similar for sows and litters housed in crates and closed swing sided pens, but significantly higher in the open swing sided pens.

When comparing all five housing treatments, the findings were similar (Table 3). Piglet mortalities in the first 24 hours were significantly lower in the crate versus closed swing pens versus open pens (Table 5). However, piglet mortalities between days 1 and 3 post-partum and day 3 to weaning were significantly higher in the OPEN swing pen compared to all other treatments (Table 5). Due to the higher piglet mortalities during the first 24 hours post-partum, total mortalities to day 3 post-partum and to weaning were higher in the shut swing pen than the crate, resulting in significantly higher mortality up to weaning (Table 4) and a significant reduction in litter size weaned (Table 6). Piglet mortalities between day 1 and 3 post-partum were higher in the OPEN swing pen compared with all other treatments, resulting in more total mortalities and a lower weaned litter size (Tables 2 and 7).

Sow LW and P2 on day 2 of lactation and at weaning were similar for all treatments; however, sows in the CRATE/PEN treatment lost more ($P < 0.05$) weight during lactation compared with all other treatments except for those housed in crates throughout lactation. Subsequent reproduction was unaffected by housing treatment (Table 6). There were no treatment effects on litter weight, individual piglet weight or within litter variation in piglet weight on day 6 post-partum or the day prior to weaning (Table 8).

Housing during parturition tended ($P = 0.093$) to affect sow cortisol levels on day one post-partum (Table 3), with levels highest in sows housed in farrowing crates and lowest in those housed in closed swing sided pens. When the interaction between day post-partum and farrowing treatment were analysed, there was a significant effect of day on sow cortisol levels (Table 4). Similarly, the proportion of sows with cortisol levels below the detectable limit of the assay (10ng/ml) was also affected by day post-partum (Table 4). There was also a tendency ($P = 0.07$) for sow cortisol levels to be affected by housing during parturition, regardless of day post-partum. Cortisol levels were lowest in the sows which farrowed in open swing pens (13.9 ± 0.54 ng / ml), highest in sows housed in crates (15.1 ± 0.38 ng / ml) and intermediate in sows housed in closed swing pens (14.1 ± 0.39 ng/ml).

Season

The number of piglets born dead was higher in winter compared with summer (Tables 2 and 5). Piglet mortality during the first 24 hours of parturition, and total mortality to weaning were significantly higher in winter compared with summer (Tables 2 and 5). However, piglet mortalities between day 3 and weaning tended to be lower in winter compared with summer ($P < 0.1$). Nevertheless, sows farrowing and lactating during winter weaned fewer piglets than those doing so during summer ($P < 0.1$). Sows farrowing during winter were lighter and had lower P2 on day 2 of lactation and at weaning compared with those farrowing during summer (Table 6). Although the change in P2 during lactation was unaffected by season, weight loss was almost five times higher during summer than winter (Table 6). Weaning to service interval was 2.4 days shorter for sows lactating during summer compared with winter; however, subsequent litter sizes were higher for sows lactating during winter compared with summer (Total born, $P < 0.05$; born alive, $P < 0.1$). Interestingly, the proportion of sows farrowing a second litter was higher during summer compared with winter (0.76 versus 0.71; $P < 0.05$). Interestingly, cortisol levels were higher in winter compared with summer on days 4 and 8 post-partum (Table 3), but similar on all other days.

Table 2 Effect of three housing systems during farrowing (farrowing crate versus open swing sided pen versus closed swing sided pen) and season on piglet mortality

	Housing during farrowing			Season	
	Farrowing Crate	Open Swing Pen	Closed Swing Pen	Winter	Summer
Litter size					
Total born	12.30±0.19	11.96±0.30	12.08±0.21	12.16±0.18	12.16±0.18
Born alive	11.35±0.18	10.83±0.28	11.11±0.19	11.05±0.17	11.28±0.17
Born dead	0.86±0.07	0.95±0.11	0.81±0.07	0.72±0.06*	0.99±0.06**
Mummies	0.09±0.03	0.18±0.04	0.16±0.03	0.11±0.02	0.15±0.02
Piglet deaths					
First 24 hours pp	$0.83±0.08^a$	$2.00±0.12^c$	$1.18±0.08^b$	1.44±0.07*	0.91±0.07*
Days 1 – 3 pp	$0.35±0.06^a$	$1.14±0.09^b$	$0.39±0.06^a$	0.48±0.05	0.54±0.06
Days 3 pp to wean	$0.07±0.03^a$	$0.32±0.05^b$	$0.15±0.03^a$	0.11±0.03**	0.18±0.03**
To day 3 pp	$1.18±0.11^a$	$3.14±0.16^c$	$1.57±0.11^b$	1.92±0.10*	1.45±0.10*
To weaning	$1.25±0.12^a$	$3.46±0.18^c$	$1.72±0.13^b$	2.03±0.11*	1.63±0.11*
Litter size weaned	$9.62±0.12^a$	$7.90±0.18^b$	$9.23±0.13^a$	9.01±0.11**	9.29±0.11**

^{abc} between different housing treatments indicate differences; $P < 0.05$; within season *$P < 0.05$, **$P< 0.1$.

Table 3 Effect of three housing systems during farrowing (farrowing crate versus open swing sided pen versus closed swing sided pen) and season on sows cortisol (ng / ml) on days 1, 4, 8 and 22 post-partum

	Housing during farrowing			Season	
	Farrowing Crate	Open Swing Pen	Closed Swing Pen	Winter	Summer
Day post-partum					
One	17.8±0.85*	16.6±1.25*	15.1±0.86*	16.7±0.76	16.3±0.77
Four	14.0±0.55	12.9±0.77	13.7±0.55	14.5±0.50[a]	12.9±0.49[b]
Eight	15.1±0.75	12.7±1.05	13.4±0.75	15.0±0.67[a]	12.9±0.66[b]
Twenty-two	13.7±0.85	13.5±1.23	14.0±0.89	14.4±0.78	13.2±0.77

[ab] between season indicate differences; P < 0.05; within season *P = 0.093

Table 4 Effect of day of parturition on sow cortisol levels (ng/ml) and the proportion of sows with cortisol levels below the detectable limits of the assay (10 ng / ml)

	Day post-partum			
	Day 1	Day 4	Day 8	Day 22
Cortisol, ng/ml	16.5 ± 0.48[b]	13.7 ± 0.48[a]	13.9 ± 0.48[a]	13.8 ± 0.49[a]
% sows with cortisol < 10 ng/ml	0.407[a]	0.520[b]	0.524[bc]	0.602[c]

[abc] within row P < 0.05

Table 5 Effect of farrowing and lactation housing treatment and season on litter characteristics and piglet survival to weaning

	Farrowing and lactation housing treatment					Season	
	SWING OPEN ALL	SWING SHUT D-1to7	CRATE / PEN	SWING SHUT to D7	CRATE ALL	Winter	Summer
Litter size							
Total born	11.96 ± 0.29	11.94 ± 0.29	12.43 ± 0.28	12.24 ± 0.29	12.19 ± 0.26	12.16 ± 0.18	12.15 ± 0.18
Born alive	10.83 ± 0.28	10.90 ± 0.27	11.50 ± 0.27	11.33 ± 0.28	11.22 ± 0.24	11.05 ± 0.17	11.28 ± 0.17
Born dead	0.95 ± 0.10	0.90 ± 0.10	0.83 ± 0.10	0.72 ± 0.10	0.88 ± 0.09	0.99 ± 0.06*	0.72 ± 0.06*
Mummies	0.18 ± 0.04	0.14 ± 0.04	0.09 ± 0.04	0.17 ± 0.04	0.09 ± 0.03	0.11 ± 0.02	0.15 ± 0.02
Piglet deaths							
First 24 hours pp	2.00 ± 0.12^{c}	1.19 ± 0.11^{b}	0.86 ± 0.11^{a}	1.17 ± 0.12^{b}	0.81 ± 0.10^{a}	1.44 ± 0.07*	0.91 ± 0.07*
Days 1 – 3 pp	1.14 ± 0.09^{b}	0.41 ± 0.09^{a}	0.40 ± 0.09^{a}	0.36 ± 0.09^{a}	0.31 ± 0.08^{a}	0.48 ± 0.05	0.54 ± 0.06
Days 3 pp to wean	0.32 ± 0.05^{b}	0.11 ± 0.05^{a}	0.07 ± 0.05^{a}	0.20 ± 0.05^{a}	0.07 ± 0.04^{a}	0.11 ± 0.03**	0.18 ± 0.03**
To day 3 pp	3.14 ± 0.16^{c}	1.60 ± 0.16^{b}	1.26 ± 0.16^{ab}	1.53 ± 0.16^{b}	1.12 ± 0.14^{a}	1.92 ± 0.10*	1.45 ± 0.10*
To weaning	3.46 ± 0.18^{c}	1.71 ± 0.18^{b}	1.33 ± 0.18^{ab}	1.73 ± 0.18^{b}	1.19 ± 0.16^{a}	2.03 ± 0.11*	1.63 ± 0.11*

^{abc} between different housing treatments indicate differences; $P < 0.05$; within season *$P < 0.05$, **$P < 0.1$.

Table 6 Effect of farrowing and lactation housing treatment and season on sow performance

	Farrowing and lactation housing treatment					Season	
	SWING OPEN ALL	SWING SHUT D-1to7	CRATE/PEN	SWING SHUT to D7	CRATE ALL	Winter	Summer
Sow Weight, kg							
Day 2	236.5 ± 3.31	231.6 ± 3.21	240.4 ± 3.13	237.8 ± 3.20	233.3 ± 2.95	227.5 ± 2.00[a]	243.8 ± 1.96[b]
Weaning	232.2 ± 3.25	228.8 ± 3.05	225.4 ± 2008	233.6 ± 3.04	225.7 ± 2.85	225.2 ± 1.93[a]	232.5 ± 1.87[b]
Sow LW change, Kg	-4.47 ± 1.86[c]	-4.03 ± 1.77[c]	-11.97 ± 1.81[d]	-5.89 ± 1.77[c]	-7.68 ± 1.68[cd]	-2.89 ± 1.13[a]	-10.35 ± 1.08[b]
Sow P2, mm							
Day 2	17.68 ± 0.62	17.44 ± 0.59	18.74 ± 0.59	18.34 ± 0.59	18.24 ± 0.55	16.97 ± 0.37[a]	19.16 ± 0.36[b]
Weaning	17.03 ± 0.54	17.33 ± 0.52	18.43 ± 0.51	17.75 ± 0.52	17.90 ± 0.48	16.88 ± 0.33[a]	18.46 ± 0.32[b]
Sow P2 change, mm	-0.43 ± 0.51	-0.11± 0.50	-0.19 ± 0.49	-0.58 ± 0.50	-0.46 ± 0.46	-0.11 ± 0.31	-0.58 ± 0.30
Subsequent Reprod.							
WSI	5.44 ± 0.97	8.26 ± 0.92	5.44 ± 1.14	7.96 ± 1.06	6.98 ± 0.89	8.09 ± 0.63[b]	5.75 ± 0.61[a]
% weaned sows mated	88%	92%	86%	86%	88%	84%	90%
Preg Rate (% mated)	94%	93%	88%	90%	89%	89%	92%
Farr Rate (% mated)	86%	87%	85%	82%	85%	85%	85%
Farr Rate (% preg.)	91%	94%	97%	92%	95%	93%	95%
Farr Rate (% weaned)	75%	80%	73%	71%	75%	73%	77%
% sows Farr. 2nd litter	74%	80%	71%	71%	72%	71%[a]	76%[b]
Total born	13.16 ± 0.58	13.28 ± 0.56	13.25 ± 0.70	12.82 ± 0.67	12.53 ± 0.54	13.57 ± 0.38[b]	12.43 ± 0.38[a]
Born alive	12.34 ± 0.53	12.34 ± 0.50	11.68 ± 0.63	12.24 ± 0.60	11.72 ± 0.49	12.54 ± 0.35*	11.62 ± 0.34*
Born dead	0.79 ± 0.19	0.67 ± 0.18	1.32 ± 0.23	0.53 ± 0.22	0.66 ± 0.18	0.88 ± 0.13	0.66 ± 0.12
Mummies	0.03 ± 0.08	0.28 ± 0.08	0.25 ± 0.10	0.05 ± 0.09	0.15 ± 0.07	0.15 ± 0.05	0.15 ± 0.05

Between season [ab] $P < 0.05$; * $P < 0.1$. Between treatment [cd] $P < 0.05$.

Table 7 Effect of farrowing and lactation housing treatment and season on piglet and litter weights

	Farrowing and lactation housing treatment					Season	
	SWING OPEN ALL	SWING SHUT D-1to7	CRATE/PEN	SWING SHUT to D7	CRATE ALL	Winter	Summer
Litter weight, kg							
Day 6	25.4 ± 1.15	23.8 ± 1.11	24.0 ± 1.30	24.7 ± 1.16	26.3 ± 1.02	24.7 ± 0.7	25.1 ± 0.71
Day before weaning	67.8 ± 4.06	65.8 ± 3.79	65.5 ± 4.44	69.7 ± 4.15	70.4 ± 3.48	67.9 ± 2.45	68.1 ± 2.48
Piglet weight, kg							
Day 6	2.5 ± 0.06	2.4 ± 0.06	2.5 ± 0.07	2.5 ± 0.06	2.6 ± 0.06	2.5 ± 0.04	2.5 ± 0.04
Day before weaning	7.9 ± 0.21	7.8 ± 0.20	7.9 ± 0.23	7.9 ± 0.22	8.3 ± 0.18	7.9 ± 0.13	8.1 ± 0.13
Variation in piglet LW, kg							
Day 6	0.2 ± 0.02	0.2 ± 0.02	0.2 ± 0.02	0.2 ± 0.02	0.2 ± 0.02	0.2 ± 0.01	0.2 ± 0.02
Day before weaning	2.0 ± 0.20	1.5 ± 0.18	1.7 ± 0.21	1.5 ± 0.20	1.6 ± 0.17	1.6 ± 0.12	1.7 ± 0.1
Litter size weaned	7.9 ± 0.18[c]	9.3 ± 0.18[b]	9.4 ± 0.17[ab]	9.2 ± 0.18[b]	9.8 ± 0.16[a]	9.0 ± 0.11*	9.3 ± 0.11*

[abc] between different housing treatments indicate differences; $P < 0.05$; within season $^*P < 0.1$.

Table 8 Effect of farrowing and lactation housing treatment and season on sow cortisol (ng/ml)

	Farrowing and lactation housing treatment					Season	
	SWING OPEN ALL	SWING SHUT D-1to7	CRATE/PEN	SWING SHUT to D7	CRATE ALL	Winter	Summer
Day post-partum							
One	16.6 ± 1.25	15.8 ± 1.21	18.9 ± 1.21	14.5 ± 1.22	16.6 ± 1.21	16.3 ± 0.78	16.7 ± 0.77
Four	12.9 ± 0.77	13.7 ± 0.79	14.5 ± 0.48	13.6 ± 0.78	14.5 ± 0.79	14.5 ± 0.50[a]	12.9 ± 0.49[b]
Eight	12.7 ± 1.05	13.9 ± 1.06	14.4 ± 1.06	12.9 ± 1.06	15.6 ± 1.05	15.2 ± 0.67[a]	12.8 ± 0.67[b]
Twenty-two	13.5 ± 1.23	15.5 ± 1.24	13.1 ± 1.20	12.5 ± 1.27	14.3 ± 1.20	14.5 ± 0.78	13.2 ± 0.77

[ab] between different seasons indicate differences; $P < 0.05$

4. Application of Research

It is clear from the current data that more piglets died when sows farrowed in open swing sided pens, and that the additional freedom of movement associated with this housing did not reduce incidences of stillbirths. It was also evident that reducing sow confinement during the first three days of lactation resulted in higher piglet mortalities. These two peaks in piglet deaths resulted in a 2-piglet reduction in litter size weaned per sow. However, it is also clear that reducing sow and litter confinement from day seven of lactation onwards did not increase the incidence of piglet mortalities, regardless of how this is achieved (i.e. opening a swing sided crate or moving sow and litter to a simple pen). The current data, along with previous data of others, and ours indicate that reducing the period of sow confinement to the 8 days around parturition (1 day before to 7 days after) may be a commercially viable option. Though the reason for the higher piglet mortality in the closed swing sided pens in the first 24 hours needs to be established. This may be a design flaw in the pens used in the study and may not apply to other freedom type farrowing pens.

In general, the data from this study is consistent with the findings from a smaller study utilizing the same housing types at the same facility (Condous et al., 2016). Consistent with the current findings, Condous et al. (2016) reported higher live born mortality during the first 24 hours after parturition and on days 1 and 2 of parturition in sows housed in open compared with closed swing sided pens and crates. This increase in piglet mortality was due to increased incidences of piglet crushing by the sow. In support of the current data, Condous et al (2016) reported no difference in piglet mortalities compared with conventional farrowing crates when the swing sided pens were opened on day 7 of lactation. However, opening the swing sided pens on day three of lactation did result in greater piglet mortalities, which may explain why more piglets in the open pens died between day 3 and weaning in the current study. The only discrepancy between this study and the study of Condous et al. (2016) is that she reported higher stillbirths in sows, which farrowed in crates compared with Open swing pens, with crated sows exhibiting longer farrowing durations and greater intervals between successive piglet births. However, the lack of an effect of confinement or non-confinement during farrowing on stillbirths in the current study is supported by other previous studies using similar housing systems. Using SWAP pens and swing-sided farrowing crates / pens, still birth rates were similar for sows, which were or were not confined during farrowing (Moustsen et al., 2013; Hales et al., 2014; Hales et al., 2015). Similar to the current study, previous studies have also demonstrated significantly higher incidences of piglet mortality when sows are allowed to farrow without confinement (e.g. Moustsen et al., 2013; Hales et al., 2014; Hales et al., 2015; Condous et al., 2017). Based on the current data and the majority of previous data, there appear to be no benefits for the piglet or farm productivity of allowing sows to farrow in open pens.

However, it is clear from the current study, as well as previous studies that sows only need confinement during parturition and for the first few days after farrowing in order to ensure piglet mortalities do no exceed those of conventional farrowing crates. Compared to confined sows and litters, removing sow confinement on day 3 (Singh et al., 2017), day 4 (Moustsen et al., 2013; Hales et al., 2015) day 7 (Condous et al., 2016) does not increase piglet mortalities. However, Condous et al. (2016) reported increased piglet mortalities, in the same facilities, when swing sided, pens opened on day three post-partum. Although not recorded in the current study, previous studies using these facilities indicated no impact of reducing sow and litter confinement on day three or seven of lactation on sow or piglet behavior (Condous et al., unpublished). However, this contrasts with recent evidence (Singh et al., 2017) of increased maternal behavior and social interaction between piglets when sows and piglets were loose housed from day three of lactation to weaning.

The secondary aim of this study was to determine whether the impact on piglet mortalities of allowing sows to farrow without confinement or removing confinement during lactation would differ between seasons. Within conventional Australian farrowing accommodation, environmental conditions differ considerably between summer and winter. Although, season affected piglet mortalities, with stillbirths and early piglet mortalities higher in winter compared with summer, this effect was consistent between housing treatments. The reason for this increase in early piglet mortalities is unclear, but it is noteworthy that sows were lighter in winter than summer (approximately 16 kg lighter after farrowing and 7 kg lighter a weaning). Lower environmental temperatures in the farrowing house could explain the greater mortality of young piglets (i.e. due to crushing, insufficient energy reserves to maintain body temperature). However, the reduced weight and P2 backfat of sows farrowing during winter may also have affected piglet viability as well as colostrum production, with both factors affected by maternal nutrition in late gestation. Unfortunately, we did not measure piglet birth weight and although piglet weights were similar on day 6 and at weaning during summer and winter, this may reflect the reduced suckled litter size of sows lactating during winter.

In addition to being heavier and fatter at farrowing and weaning, sows which farrowed and lactated during summer were mated 2.3 days earlier after weaning, but produced 1 piglet less at the subsequent farrowing. During summer, sows did lose more weight during lactation, but were heavier and fatter at weaning than those, which farrowed and lactated during winter. Interestingly, sows were more likely to farrow a second litter when they farrowed in summer compared with winter (76% versus 71%). As consequence, the number of piglets subsequently produced per 100 sows farrowing initially during summer compared with winter was 945 versus 964 (total born) and 883 versus 890 (live born). The reason for this apparent differential effect of season of farrowing on weaning to service interval and subsequent litter size is unclear, but probably relates to the dynamics of body weight change during lactation. It could be argued, based on these data, that absolute liveweight and P2 backfat at farrowing and weaning determine the capacity to return to reproductive function post-weaning, but that the degree of catabolism (weight loss) during lactation affects the number and quality of the ova produced, and thus litter size. Alternatively, the delayed weaning to service interval during winter may have allowed increased recovery from the metabolic demands of lactation, resulting in a larger, and better quality, pool of follicles and oocytes being available for ovulation and fertilization. Regardless, it is clear that further work is required to understand how body weight and P2 backfat at farrowing and weaning, as well as weight and fat loss during lactation, affect subsequent reproduction. Specifically, controlled, prospective studies might confirm whether increasing sow weight and fatness at farrowing during summer reduces the weaning to oestrus interval, but negatively affects weight loss and thus subsequent litter size.

The pattern of cortisol release observed in the current study is consistent with the literature. In our study, cortisol levels were high on day 1 post-partum, decreased to day 4 and remained unchanged thereafter. Previously, cortisol levels have been shown to decline from day 1 to 2 (Jarvisab et al., 1998) and day 7 post-farrowing in gilts (Sorrells et al., 2007), with cortisol levels similar in weeks 1, 2 and 3 post-partum in sows housed individually in open pens (Thomsson et al., 2015). In contrast to previous suggestions (e.g. Jarvis et al., 2006) that long-term confinement may increase the stress response of lactating sows, the proportion of sows with low cortisol levels (i.e. below the detectable limit of the assay) increased significantly between days 4 and 22 post-partum.

Cortisol levels tended to be lower in sows, which farrowed and lactated in open swing pens compared with those, which farrowed in crates, which could be indicative of reduced stress in these animals. Previously, Tilbrook et al. (2006) demonstrated that the presence of lambs reduced the stress response in lactating sheep; however, this physiological adaptation has not been investigated in pigs. Thomson et al. (2015) demonstrated a reduction in cortisol levels in lactating sows moved to multisuckle pens in week 3, but not in weeks 1 and 2. This could suggest that cortisol levels are naturally elevated during the first 14 days of lactation in sows; but that changes in environment can affect stress (as demonstrated by changes in cortisol), as lactation progresses. The marginal effects of housing on cortisol levels observed in our study could simply be because the differences in housing type was not large enough to have an effect.

Interestingly, cortisol levels were higher during winter compared with summer on days 4 and 8 post-partum. This is contrary to what we expected, given the traditional expectation that elevated temperature, and heat stress, would increase cortisol levels, at least in late lactation (Barb et al., 1991). However, Bacci (et al., 2014) reported lower cortisol in hair samples collected from sows during summer compared with winter. In guinea pigs, low temperatures resulted in lower cortisol levels; however, the amplitude of the cortisol response to an induced stressor was higher (Michel et al., 2011). Together, these studies could suggest that the elevated cortisol observed in sows lactating during winter was merely a reflection of a heightened response to the same stressor, and not an increased level of stress.

5. Conclusion

It is clear from the study that opening swing sided pens during parturition, and keeping them open after parturition does not increase the number of live born piglets produced and increases the number of liveborn piglets, which die during the first three days of lactation. Our findings are consistent with those of other groups, which support the current evidence that freedom farrowing does not reduce stillbirths and increases live born piglet mortality. Consistent with our previous work (Condous et al., 2016), removing sow and litter confinement on day seven of lactation (either by opening the swing sided pen or moving to a simple non-confinement pen) did not result in an increase in piglet mortalities when compared with conventional crate housing during the equivalent time. Our previous data (Condous et al., 2016) also indicated that removing sow confinement on day three post-partum was too early, as evidenced by a rise in piglet deaths. These data are promising from a commercial perspective, as they provide substantial evidence that sow confinement can be reduced to the 8 days around parturition, without negatively impacting litter size weaned and or piglet weights at weaning. However, we require more information from litters housed in open swing pens or simple non-confinement pens from day seven of lactation to weaning to confirm there are no negative effects on piglet growth. Cortisol levels did tend to be lower in sows housed in open swing crates compared with farrowing crates; however, this needs to be considered in relation to the increase in piglet mortality in this housing system. Interestingly, regardless of housing system the proportion of sows with low cortisol levels (i.e. below the minimum detection limit for the assay; 10 ng / ml) increased significantly between days 4 and 22 of lactation. Importantly, it is also clear from the current data that housing sows in farrowing crates during, and for the seven days following; parturition resulted in the lowest incidence of piglet mortalities.

6. Limitations/Risks

The greatest limitation of this body of work is that it was conducted using only one type of freedom farrowing pen (i.e. open swing sided pen). There is, therefore, an argument that both still birth rates and early live born mortality may have been lower in ‘designed’ free farrowing pens (e.g. PIGSAFE), or smaller swing sided pens (e.g. 360 pens). To my knowledge, this is one of the largest data sets comparing piglet survival and performance in commercially relevant modified farrowing crates / pens (at least in Australia). The other limitation is that these data relate to one site, and under South Australian conditions. Therefore, it would be beneficial for the Australian industry for more data to be collected (from this, and other sites across the country) to provide even greater confidence that non-confinement from day 7 of lactation onwards, or even day 4 onwards, does not affect piglet survival and weight at weaning. It would also be beneficial to collect serial blood samples (2 – 4 times daily) for measurement of cortisol and other markers of stress throughout lactation to determine more accurately the impact of housing on sow stress.

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

- Confinement of sows during and for the first seven days after farrowing is necessary to prevent a rise in piglet mortalities and a reduction in weaned litter size.
- Sows and their litters can be housed individually, in the absence of a conventional crate (e.g. open, simple pen of open, swing sided crate) from day seven of lactation without increasing piglet mortalities or reducing litter size or weight at weaning.

- The farrowing crate results in the lowest incidence of early deaths of liveborn piglets
- Future work should focus on four areas:
    1. Increasing the welfare of sows housed in confinement during parturition and the first seven days of lactation
    2. Investigating whether the use of designed freedom farrowing pens (e.g. PIGSAFE, in which lower stillbirths and comparable early piglet survival have been reported) for the first seven days of lactation followed by moving sows and litters to a simple (cheap) pen is a viable commercial option
    3. Determine whether sow and litter confinement can be removed earlier in lactation (e.g. day 4), without impairing litter weights and sizes at weaning
    4. Generation of more data, from multiple national sites, and housing types is important to generate producer confidence in systems, which reduce sow confinement to the 7 – 10 days around parturition.

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