FENCE-LINE BOAR EXPOSURE AT THE END OF LACTATION TO IMPROVE REPRODUCTIVE PERFORMANCE OF GROUP HOUSED SOWS AND THE IDENTIFICATION OF SOWS THAT SPONTANEOUSLY OVULATE DURING LACTATION

Report prepared for the
Co-operative Research Centre for High Integrity Australian Pork

Project 1A-118

By

Dr William van Wettere[1] and Rebecca Morrison[2]

[1]School of Animal and Veterinary Sciences
The University of Adelaide
South Australia 5005

[2]Rivalea Australia
Redlands Road Corowa
New South Wales 2646

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Executive Summary

Background: Increasing litter size and farrowing frequency is the key to increasing reproductive efficiency of the sow breeding herd and improving overall feed conversion efficiency. Previously, we have demonstrated that increasing fenceline boar exposure in conjunction with either temporary removal of the litter or group housing at the end of lactation can improve reproductive performance (increased litter size) of sows mated after weaning. While the ability to reliably stimulate lactation can be beneficial for reproductive efficiency, there are also incidences when lactation oestrus is not an attractive option, and sows which ovulate spontaneously during lactation effectively disrupt the efficiency of the production system. The percentage of sows which ovulate spontaneously during lactation can be unpredictable and variable between batches, and is as high as 24 – 34% of sows (van Wettere et al., 2017). Developing accurate, non-invasive and easy to use strategies to detect ovulation in the farrowing shed may be beneficial for producers. The current study had two aims. One, to determine whether four days of fence line boar exposure in the last week of lactation reduces the weaning to mating interval in either farrowing crates or group lactation, and increases subsequent litter sizes, without inducing lactation oestrus. Two, to determine whether changes in vulval temperature accurately identify the timing of oestrus in weaned sows.

Methods: This study was conducted at Rivalea Australia using sows which farrowed between June and November, 2017 (n = 501 sows, parity 1 – 7). There were three treatments. Sows were housed in crates and received either no boar exposure during lactation (Control); or fenceline boar exposure (BE) for the last 4 days of lactation (Crate+BE); or housed in groups for the last 7 days of lactation and received fenceline BE for the last 4 days of lactation (Group+BE). Sows were weaned 27 days post-farrowing, and mated at their first detected oestrus

Results: There were no differences between treatments for sow live weight or weight change during lactation, suckled litter size or litter size weaned during the lactation at which treatments were imposed. The incidence of lactational oestrus was higher ($P<0.05$) in the Group+BE (22.4%) compared with Crate+BE (8.3%) and Control (1.5%) treatments. The percentage of sows expressing oestrus within 5 days of weaning was higher in the Control (67.2%) and Crate+BE (62.8%) compared with Group+BE (51.2%). Overall weaning to oestrus interval was shorter for the Group+BE compared with Control and Crate+BE treatments. Of those sows which failed to express oestrus behaviour prior to day 7 post-weaning, 93% (Control; 14/15 sows bled), 76% (CrateBE; 16/21 sows bled) and 80% (Group+BE; 8/10 sows bled) had functional corpora lutea on day 7 post-weaning (based on progesterone levels). Treatment did not affect subsequent farrowing rate, or subsequent litter size. Mating sows in lactation resulted in fewer total and live piglets born at the subsequent lactation ($P<0.1$) and lower farrowing rates ($P<0.05$). Vulval temperature rose significantly from day -2 to day 0 of oestrus. Short pregnancies ($\leq$114 days; 14% of pregnancies) resulted in more piglets dying prior to fostering, and there was a significant correlation in pregnancy length between successive pregnancies.

Conclusion: Based on the current data, four days of fenceline boar exposure prior to weaning did not improve reproductive performance of sows mated post-weaning. Furthermore, the fertility and fecundity of sows mated during lactation was lower than those mated post-weaning. Although, increasing vulval temperature was associated with oestrus, further research is required to determine if it reliably predicts oestrus and ovulation when used in isolation. In support of previous data, this study demonstrated that short pregnancies result in increased mortality of new born piglets.

Acknowledgements

We wish to acknowledge the intellectual input of Dr Rebecca Athorn who was involved in the development of this project and to Erin Ford and the Rivalea Research and Innovation and Production teams who were involved in this project.

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Table of Contents

1. Introduction

Subsequent litter size was significantly higher following mating after weaning when sows were housed in groups and received daily fenceline boar exposure for the last seven days of lactation (Greenwood, PhD Thesis). This increase in litter size equated to an additional 2 – 3 piglets compared to sows housed in crates (without any boar exposure) and mated post-weaning, as well as a significant reduction in weaning to oestrus interval. This outcome is supported by previous work (van Wettere, unpublished) which demonstrated that a short period (7 hours) of sow-piglet separation in conjunction with fenceline boar exposure, improved subsequent reproductive performance of sows compared with sows that remained anoestrus during lactation and were mated post-weaning. Size and maturity of the ovarian follicles present at weaning, as well as the pattern of luteinizing hormone (LH) release prior to weaning, determine the timing of the post-weaning oestrus, and subsequent litter size (Lucy et al., 2001; van Wettere et al., 2017). It is speculated that the improved subsequent litter size of group-housed, boar-exposed lactating sows (Greenwood) and individually housed, boar-exposed sows (van Wettere) reflected the combination of reduced suckling frequency (reduced inhibition of LH) and the stimulatory effects of boar component stimuli on LH release and follicle growth. As a result, sows possessed a more developed or mature antral follicle pool at weaning, which would explain the more rapid return to oestrus post-weaning and the improved litter size.

The ability to stimulate lactation oestrus provides a number of benefits to production systems, including the ability to reduce the farrowing to farrowing interval, eliminate mating stalls and wean at a time which suits the piglet rather than the producer. However, there are also incidences when lactation oestrus is not an attractive option, and sows which ovulate spontaneously during lactation effectively disrupt the efficiency of the production system. The percentage of sows which ovulate spontaneously during lactation can be unpredictable and variable between batches, and as high as 24 – 34% of sows (van Wettere et al., 2017). Technologies, such as infra-red thermal cameras for monitoring vulval temperature changes (temperature of the vulva rises prior to ovulation; Sykes et al., 2012; Simoes et al., 2014) alongside behavioural (drop in feed intake, restlessness) and physical indices (vulval swelling, presence of mucus) may aid in the detection and determination of lactation oestrus in the farrowing house in the absence of the boar. Thermal imaging of the vulva has been suggested as a way to identify oestrus and estimate timing ovulation in sows (Sykes et al., 2012; Simoes et al., 2014) and dairy cattle (Talukder et al., 2015), and may, therefore, be a useful tool for identifying which sows spontaneously ovulate during lactation. If mating sows in the farrowing house is not the intention, identification of sows which ovulate during lactation the approximate timing of ovulation may assist with management after weaning, thus reducing the negative impact on mating targets.

The current study had two aims:

1. To determine whether four days of fenceline boar exposure at the end of lactation reduces the farrowing to farrowing interval, and increases subsequent litter sizes, without inducing lactation oestrus. This project

determined the reproductive efficiency of three housing / management systems for lactating sows. System one, sows individually housed during lactation, with fenceline boar exposure commencing post-weaning. System two, sows individually housed during lactation, with fenceline boar exposure commencing four days before weaning. System three, sows group housed for the last seven days of lactation, with fenceline boar exposure commencing four days before weaning.

2. To determine whether changes in vulval temperature accurately identify the timing of oestrus in weaned sows, and to use changes in vulval temperature to identify sows who have spontaneous lactation oestrus in conventional farrowing house systems in the absence of boar exposure.

2. Methodology

This study was conducted at Rivalea, Australia using 501 sows. The experiment was approved by the Rivalea Animal Ethics Committee. All animal procedures were conducted with prior institutional ethical approval under the requirement of the NSW Prevention of Cruelty to Animals Act 1985 in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organisation/Australian Animal Commission 'Australian code of practice for the care and use of animals for scientific purposes'. The experiment was conducted across 10 time replicates, using sows mated between March and July 2017, farrowing between June and November 2017 and weaned between July and December 2017. Sows were allocated to one of three treatment groups (Table 1):

Table 1 Experimental treatments

Treatment	Housing	Start of boar exposure	Number of sows	Parity at start of lactation (range)	Lactation length (days)
Control	Farrowing crate throughout lactation	Day 4 post-weaning	165	3.1 ± 0.13 (1 – 7)	26.6 ± 0.20
Crate+BE[1]	Farrowing crate throughout lactation	4 days before weaning	196	3.1 ± 0.12 (1 – 7)	27.2 ± 0.18
Group+BE[1]	Group housing last 7 days of lactation	4 days before weaning	140	3.1 ± 0.15 (1 – 7)	27.2 ± 0.21

[1]Boar Exposure Treatment

Housing and management

The farrowing crates (total area 2.3 × 1.7 m) contained a creep area that was heated using a mat below (1.1 × 0.40 m) and a lamp overhead. Piglets were tail docked and received an iron injection within 2 days of birth, as per standard commercial practice. Minimal cross fostering was conducted, and, when it was required, mostly occurred within 24 h of birth. The two group lactation (GL) pens were located in one room but in the same unit that contained the farrowing crates - adjacent to the farrowing crate rooms. The two Group Lactation pens had the capacity to house 7 sows and their litters at 8.1 m^2/sow (6.0 × 9.5 m). Each group lactation pen had a solid partition with sloped walls, two heated creep areas with lids and rice hulls for bedding, and a piglet access only zone with creep feed and a water trough (Figure 1). The flooring of group lactation pens were partially slatted and rice hulls were scatted on the solid portion of the flooring weekly.

At mixing in the groups lactation pens (7 days before weaning), piglets were transferred from their crates and confined in one of the two creeps located in their lactation pens. Once all the piglets had been moved, sows were transferred from their crates to the pen. Mixing of sows and litters into group lactation pens occurred with the hours of 0730 and 0930, and was completed within approximately 30 min.

Cool drippers over the farrowing crates as well as over the dunging area of the group lactation pens were activated (3 min on and 15 min off) when the internal temperature exceeded 26ºC. Creep heat lamps were deactivated when the temperature exceeded 24 ºC. During lactation, sows were fed a standard pelleted lactation diet *ad libitum* (14.9 MJ DE/kg and 16.2% crude protein). For sows in farrowing crates, this was provided up to three times daily, based on individual sow intake. The group lactation pens were fitted with a single *ad libitum* feed hopper that catered for seven sows. Water was supplied *ad libitum* via one nipple drinker and one water trough per group lactating pen. Piglets in all housing treatments were offered creep feed from 14 days of age.

Daily boar exposure (BE) commenced four days prior to weaning date in both the Crate+BE and Group+BE treatments, In the Group+BE treatment, the boar was moved to the aisle between the two group pens, where he remained for 40 minutes before being returned to his own pen. In the Crate+BE treatment, the boar was walked down the aisle in front of the farrowing crates, during which time he was supervised by technical officers , with one staff holding a board in front of him and the other behind him, in order to hold him in front of the sows. The amount of time the boar spent in front of each sow varied depending on the interest shown by the sow (max time = 5 minutes). The boar remained in the shed for at least 40 minutes, during which time he made several circuits of the room.

Experimental Measures

The following measures were collected: Pregnancy length, lactation length, litter size (total born, born alive, stillborn, mummies), litter size post-fostering and piglet deaths and removals to weaning. Sows were weighed and caliper scored at entry into the farrowing shed and at weaning. Timing of oestrus was recorded for all sows, as was subsequent pregnancy length, and subsequent litter size (total born, born alive, stillborn and mummies). Blood samples were collected from sows which failed to return to oestrus within 7 days of weaning, and analysed for progesterone levels.

In addition, the following data was recorded from the sows housed in farrowing crates throughout lactation (Control and Crate+BE): vulva temperature (infra-red camera), vulva swelling (0 – 2; where 0 = no swelling) and reddening score (0 – 2; where 0 = no reddening) twice daily for the last 7 days of lactation. In addition, vulva temperature were recorded for 80 weaned sows twice daily from day 2 post-partum until the end of first oestrus (or day 10 post-weaning, whichever came first.

Table 2 Restlessness Scoring

Sign	Score
Sow laying down asleep	0
Sow sitting up or feeding piglets	1
Sow standing up and alert	2
Sow standing up and making vocalisations	3

Analyses

Blood plasma progesterone was determined in the Adelaide Research Assay Facility by coated tube radioimmunoassay (IM1188; Beckman Coulter, Brea, CA, USA). Briefly, 50 uL sample or standards were incubated in the supplied coated tubes with 500ul of provided iodinated Progesterone tracer solution for 1 hour at room temperature at ~200rpm on a shaking platform. The supernatant was aspirated and the radioactivity determined in a gamma counter. Levels of progesterone were calculated by interpolation from the standard curve. The lowest level of quantitation (LLoQ) of the assay was 0.2ng/ml and the intra-assay coefficient of variation was 4.5%

Data were analysed using Genstat (version 15; VSN International Ltd., Hemel Hempstead, UK). Unless otherwise specified, data are presented as Mean ± SEM, with significance accepted at $P<0.05$, and tendencies at $P<0.1$. Treatment effects on all parameters were analysed using an Analysis of Variance (ANOVA; unbalanced treatment design). Gestation length was included in the model as a co-variate when determining treatment effects on litter size. Treatment effects on the proportion of sows returning to service at set intervals and pregnancy rates were analysed using a chi-squared. Sows were divided into groups based on whether or not they expressed oestrus during lactation, and the effect of lactation oestrus and its interaction with treatment on all parameters was determined using an ANOVA (unbalanced treatment design). The number of piglets born dead, and the incidence of pre-foster mortality were not normally distributed and, therefore, a general linear mixed model (binomial) was used, with total litter size included, to determine treatment effects on this measurement (non-transformed means and SEM presented). Correlations between variates were analysed using a simple linear regression model. Irrespective of treatment, and pregnancy number (i.e. prior to start of treatment or post-treatment), three groups were created based on sow pregnancy length (short; $\leq$ 114 days), normal (115 and 116 days) and long (>116 days). The effect of pregnancy length on litter size and pre-foster piglet mortality was analysed using an Analysis of Variance (ANOVA; unbalanced treatment design).

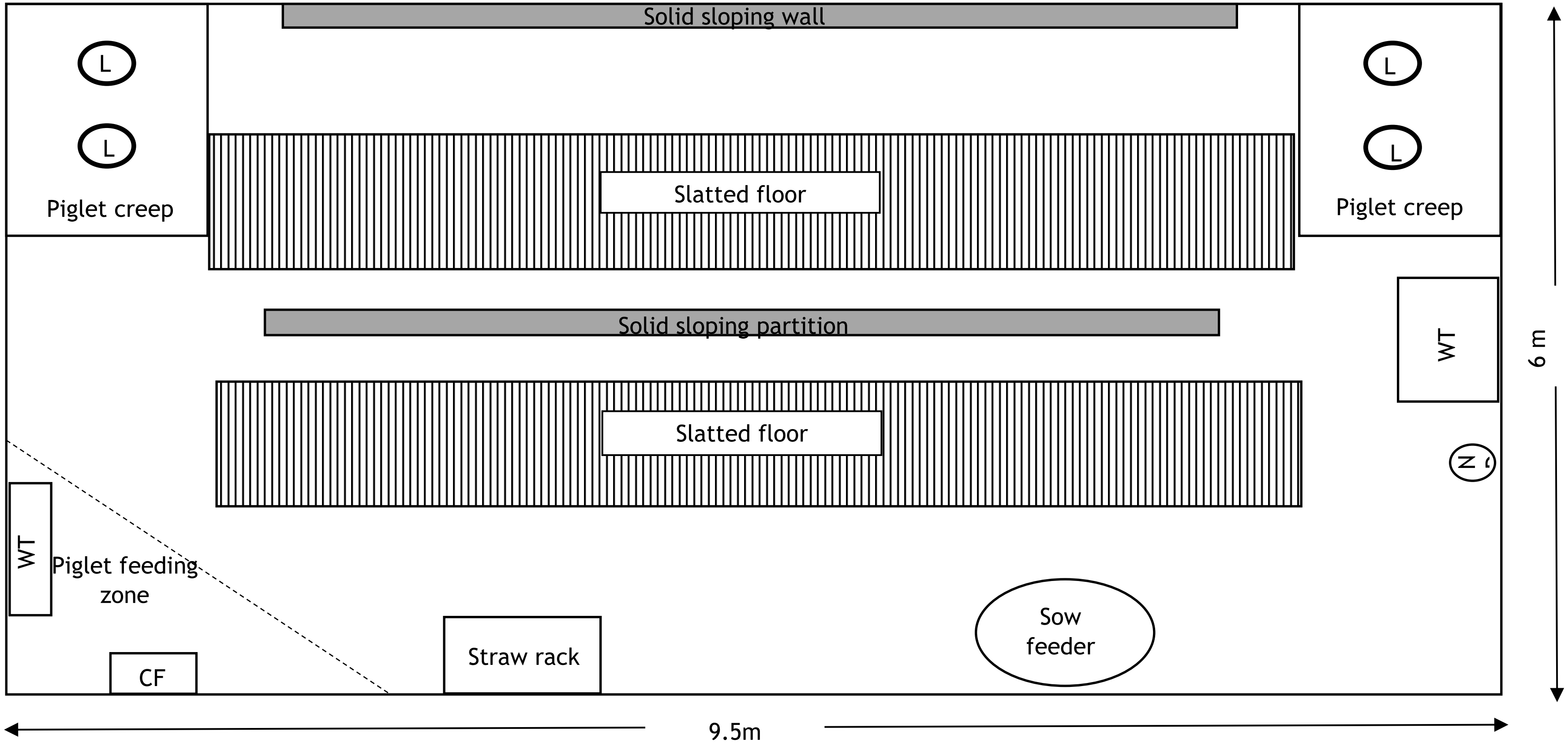

***Figure 1** Plan of group lactation pens within the lactation unit. Creep dimensions were 2.0 × 1.2 m. CF = creep feed, WR = water trough, L = heat lamp, ND = nipple drinker.*

3. Outcomes

A total of 89 sows were removed from the trial after farrowing, for a variety of reasons, including: age, lameness, poor mothering ability and health reasons. As a consequence, data presented for the Control, Crate+BE and Group+BE treatments is from 131, 156 and 125 sows, respectively. As expected, there were no differences in live weight and caliper reading at farrowing crate entry or weaning between treatments (Table 3). Live weight change and change caliper reading score from farrowing crate entry to weaning were similar for all three treatments (Table 3). Also as expected, litter size (Total born, born alive, stillbirths and mummies) were similar for all treatments at the farrowing prior to the imposition of treatment. Suckled litter size following post-foster, on day 7 prior to weaning (when sows and litters were moved to groups; Group BE) and at weaning were similar for all treatments (Table 3). Piglet deaths prior to 7 days before weaning were similar for all treatments; however, significantly fewer piglets died during the last 7 days of lactation in the Group+BE treatment (Table 3).

Regardless of housing treatment, BE increased the incidence of lactation oestrus (Table 4). However, the incidence of lactation oestrus was highest in the Group+BE treatment (Table 4). The incidence of sows expressing oestrus between days 1 and 4 post-weaning was lower in the Group+BE compared with Control and Crate+BE treatments (Table 4). Weaning to oestrus interval was shorter ($P<0.05$) for sows in the Group+BE versus Control and Crate+BE treatments (

Treatment	Control		Crate + BE	
Timing of oestrus (of mating)	***Lactation***	***Post-Wean***	***Lactation***	***Post-***
No. of sows	2	129	13	14
Weaning to service interval, days	0.00 ± 0.00^{cf}	5.67 ± 0.39^{df}	-2.15 ± 1.23^{cf}	5.74 ±
Farrowing Rate, %				
Total	100.0%	86.0%	53.0%	85.
Adjusted*	100.0%	86.9%	53.0%	88.
Subsequent Litter size				
Total born	13.86 ± 2.46^{c}	14.55 ± 0.33^{d}	11.89 ± 1.22^{c}	13.97 ±
Born alive	12.74 ± 2.24^{a}	13.03 ± 0.30^{b}	10.64 ± 1.11^{a}	12.50 ±
Born dead	1.05 ± 1.10	1.13 ± 0.15	1.12 ± 0.55	1.17 ±
Mummies	0.07 ± 0.51	0.39 ± 0.07	0.12 ± 0.25	0.31 ±
Post-foster	11.68 ± 1.17^{f}	12.10 ± 0.16^{f}	11.51 ± 0.59^{fg}	11.70 ±

Within row means with different superscripts differ: ^{ab} $P < 0.1$, ^{cd} $P < 0.05$ indicate differences betwee
0.01 indicate differences between treatments; ****adjusted farrowing rate, calculated based on reprodu***

). Interestingly, 90% or more of sows which failed to express by oestrus prior to day 8 post-weaning had detectable levels of progesterone, with 93% (Control), 76% (CrateBE) and 70% (GroupBE) of sows having progesterone levels in excess of 4 ng / ml (a level which is indicative of having ovulated).

There were no treatment effects on subsequent farrowing rate, subsequent total born, subsequent born dead or the number of mummies produced at the subsequent farrowing (

Treatment	Control		Crate + BE	
Timing of oestrus (of mating)	***Lactation***	***Post-Wean***	***Lactation***	***Post-V***
No. of sows	2	129	13	14
Weaning to service interval, days	0.00 ± 0.00^{cf}	5.67 ± 0.39^{df}	-2.15 ± 1.23^{cf}	5.74 ±
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Within row means with different superscripts differ: ^{ab} P < 0.1, ^{cd} P < 0.05 indicate differences betwee 0.01 indicate differences between treatments; ****adjusted farrowing rate, calculated based on reprodu***

). However, at the subsequent lactation, litter size post-fostering was lower for sows in the Group+BE compared with Control treatment group (11.54 ± 0.17 versus 12.06 ± 0.17; P < 0.05; Table 5). Sows which were mated during lactation had lower farrowing rates (67.4 versus 87.7; P<0.05) and gave birth to fewer piglets (total born: 12.76 ± 0.95 versus 14.11 ± 0.20; P < 0.05; and born alive: 11.58 ± 0.87 versus 12.66 ± 0.18; P < 0.1) at the subsequent farrowing (

Treatment	Control		Crate + BE	
Timing of oestrus (of mating)	***Lactation***	***Post-Wean***	***Lactation***	***Post-V***
No. of sows	2	129	13	14
Weaning to service interval, days	0.00 ± 0.00^{cf}	5.67 ± 0.39^{df}	-2.15 ± 1.23^{cf}	5.74 ±
Farrowing Rate, %				
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Mummies	0.07 ± 0.51	0.39 ± 0.07	0.12 ± 0.25	0.31 ±
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Within row means with different superscripts differ: ^{ab} P < 0.1, ^{cd} P < 0.05 indicate differences betwee 0.01 indicate differences between treatments; ****adjusted farrowing rate, calculated based on reprodu***

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When sows were divided in groups according to pregnancy length, total litter size was lower for sows with long (> 116 days) compared with normal (115 and 116 days) or short (< 114 days) pregnancies (Table 6). While pregnancy length did not affect the number of piglets born alive and born dead, or the number of mummified fetuses produced, the number of pre-foster deaths was higher (P<0.05) for sows with short compared with normal and long pregnancies (Table 6). Post-foster litter size was also lower for sows with short pregnancies compared with those with normal pregnancy lengths, despite numerically higher total litter sizes (Table 6). There was also a significant, positive correlation between pregnancy length prior to the imposed treatment and the subsequent pregnancy length ($P<0.001$; $r = 0.30$).

An insufficient number of sows expressed oestrus during lactation in the Crate+BE and Control treatments to allow analyses of the relationship between restlessness score and vulval score and oestrus. However, day relative to oestrus detection post-weaning did affect ($P<0.05$) vulval temperature with vulval temperature on day of oestrus higher than on days -2 and -3 relative to oestrus (Figure 2).

Table 3: Sow and litter characteristics during the lactation in which treatment was applied

	Control	Crate+BE	Group+BE	*P Value*
Number of sows with complete records	131	156	125	
Parity	2.6 ± 0.12	2.6 ± 0.11	2.7 ± 0.13	*0.864*
Gestation length, days	116.1 ± 0.12	116.0 ± 0.11	115.9 ± 0.13	*0.137*
Litter size				
Total born	14.13 ± 0.30	14.26 ± 0.27	13.35 ± 0.31	*0.072*
Born alive	13.09 ± 0.27	12.93 ± 0.25	12.25 ± 0.28	*0.080*
Stillborn	0.80 ± 0.09	0.91 ± 0.08	0.81 ± 0.10	*0.778*
Mummies	0.24 ± 0.06	0.43 ± 0.05	0.29 ± 0.06	*0.438*
Suckled litter size				
Post-foster	11.97 ± 0.15	12.16 ± 0.13	11.78 ± 0.15	*0.120*
7 days < Wean	10.05 ± 0.18	10.38 ± 0.17	10.16 ± 0.19	*0.911*
Weaning	9.95 ± 0.18	10.24 ± 0.17	10.14 ± 0.19	*0.974*
Piglet deaths / litter				
Day 1 to Wean – 7d	1.65 ± 0.14	1.79 ± 0.13	1.54 ± 0.14	*0.512*
Wean – 7d to Wean	0.12 ± 0.03^{b}	0.14 ± 0.03^{b}	0.02 ± 0.03^{a}	*0.008*
Sow Live weight, kg				
D110 gestation	259.2 ± 2.92	263.2 ± 2.67	262.5 ± 3.00	*0.871*
Weaning	242.1 ± 3.00	244.3 ± 2.76	241.7 ± 3.08	*0.866*
Live weight change, kg	-17.1 ± 1.23	-19.0 ± 1.13	-20.8 ± 1.26	*0.198*
Caliper Reading				
Farr. Crate Entry	12.4 ± 0.20	13.0 ± 0.18	12.9 ± 0.20	*0.719*
Weaning	12.5 ± 0.22	12.4 ± 0.20	12.4 ± 0.23	*0.910*

Caliper change	0.09 ± 0.17	-0.68 ± 0.16	-0.56 ± 0.17	*0.453*

[ab] within row indicates significant differences; P < 0.05

Table 4 Effect of treatment (Control, Crate+BE, Group+BE) on the percentage of sows expressing oestrus during specific time points during lactation, and circulating progesterone levels in sows failing to express oestrus by day 7 post-weaning

	Control	Crate+BE	Group+BE	*P value*
Oestrus Expression, % sows				
– 7d to wean*	1.5%[a]	8.3%[b]	22.4%[c]	*<0.05*
Day 1 – 4	67.2%[a]	62.8%[a]	51.2%[b]	*<0.05*
Day 5 – 7	19.1%	15.4%	16%	*>0.05*
>Day 7 plus anoestrus sows	12.2%	13.5%	10.4%	*>0.05*
Progesterone, ng/ml#	20.7 ± 2.81	20.4 ± 2.28	16.7 ± 3.41	>0.05
% sows with P4 > 0.2 ng/ml^	93%	95%	90%	>0.05
% sows with P4 > 4 ng/ml^	93%	76%	70%	>0.05

[abc] within row indicates significant differences; P < 0.05; *lactation oestrus; #sows with no oestrus expression by day 8 post-weaning; ^% sows with no oestrus expression by day 8 post-weaning

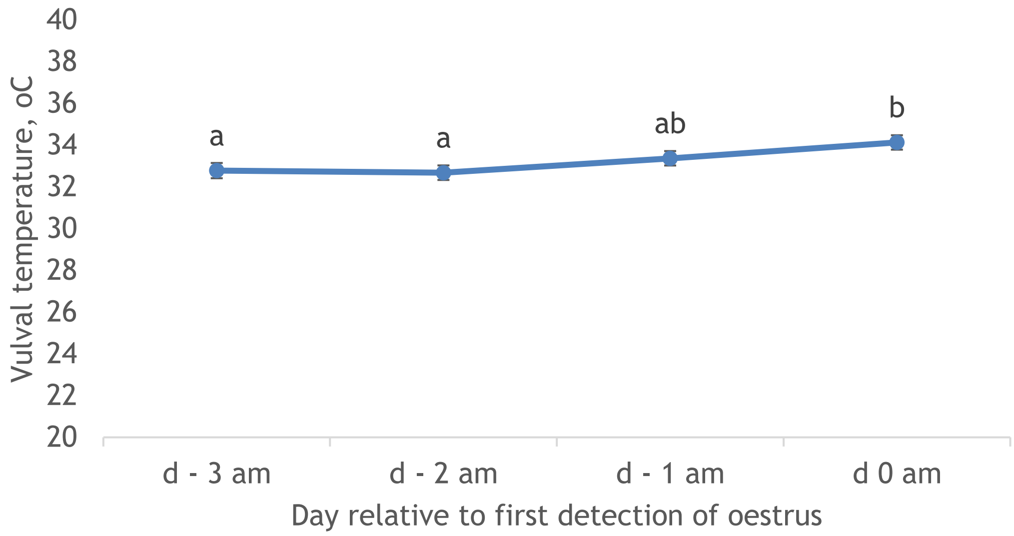

Figure 2 Mean vulval temperature of sows collected in the morning on days 3, 2, 1 and 0 prior to first oestrus detection following weaning ([ab] indicates significant differences).

Table 5 Effect of treatment and timing of oestrus (during lactation versus post-weaning) on subsequent reproductive performance

Treatment		Control		Crate + BE		Group + BE	
Timing of oestrus (of mating)		***Lactation***	***Post-Wean***	***Lactation***	***Post-Wean***	***Lactation***	***Post-Wean***
No. of sows		2	129	13	143	28	97
Weaning to service interval, days		0.00 ± 0.00^{cf}	5.67 ± 0.39^{df}	-2.15 ± 1.23^{cf}	5.74 ± 0.37^{df}	-1.79 ± 0.84^{cg}	5.51 ± 0.45^{dg}
Farrowing Rate, %							
	Total	100.0%	86.0%	53.0%	85.3%	67.9%	90.4%
	Adjusted*	100.0%	86.9%	53.0%	88.4%	67.9%	91.1%
Subsequent Litter size							
	Total born	13.86 ± 2.46^{c}	14.55 ± 0.33^{d}	11.89 ± 1.22^{c}	13.97 ± 0.31^{d}	12.65 ± 0.80^{c}	13.79 ± 0.38^{d}
	Born alive	12.74 ± 2.24^{a}	13.03 ± 0.30^{b}	10.64 ± 1.11^{a}	12.50 ± 0.29^{b}	11.47 ± 0.72^{a}	12.45 ± 0.34^{b}
	Born dead	1.05 ± 1.10	1.13 ± 0.15	1.12 ± 0.55	1.17 ± 0.14	0.53 ± 0.36	0.95 ± 0.17
	Mummies	0.07 ± 0.51	0.39 ± 0.07	0.12 ± 0.25	0.31 ± 0.07	0.64 ± 0.17	0.39 ± 0.08
	Post-foster	11.68 ± 1.17^{f}	12.10 ± 0.16^{f}	11.51 ± 0.59^{fg}	11.70 ± 0.15^{fg}	11.75 ± 0.38^{g}	11.52 ± 0.18^{g}

Within row means with different superscripts differ: ^{ab} $P < 0.1$, ^{cd} $P < 0.05$ indicate differences between lactation and post-weaning oestrus; ^{fg} $P < 0.01$ indicate differences between treatments; ****adjusted farrowing rate, calculated based on reproductive failures only***

Table 6 Effect of gestation length on litter size and pre-foster piglet survival

	Pregnancy length			
	Short (≤ 114 days)	Normal (115 and 116 days)	Long (> 116 days)	*P value*
No. Pregnancies (%)	109 (14%)	404 (53%)	246 (32%)	
Pregnancy length, days	113.6 ± 0.06[a]	115.6 ± 0.03[b]	117.5 ± 0.04[c]	*<0.01*
Litter size				
Total born	14.77 ± 0.33[a]	14.22 ± 0.17[a]	13.20 ± 0.22[b]	*<0.01*
Born alive	12.72 ± 0.13	12.70 ± 0.07	12.60 ± 0.09	*0.796*
Born dead	0.99 ± 0.12	0.92 ± 0.06	0.97 ± 0.08	*0.823*
Mummies	0.26 ± 0.06	0.35 ± 0.06	0.37 ± 0.04	*0.381*
Pre-foster deaths	0.80 ± 0.09[b]	0.55 ± 0.05[a]	0.48 ± 0.06[a]	*<0.05*
Post-foster litter size	11.65 ± 0.14[a]	12.04 ± 0.07[b]	11.77 ± 0.09[ab]	*<0.05*

[ab] within row indicates significant differences; $P < 0.05$

4. Application of Research

The data from this study failed to support the hypothesis that providing sows with fenceline boar exposure during late lactation would increase the fertility and fecundity of those sows which were mated after weaning. The current data demonstrated that vulval temperature increased significantly during the two days prior to detection of oestrus in weaned sows. However, the incidence of lactation oestrus was too small to allow reliable associations between vulval temperature and lactation oestrus to be determined. Therefore, while increases in vulval temperature may facilitate detection of oestrus, behavioural signs of oestrus (i.e. standing reflex, interest in the boar) are likely to be more accurate.

In the current study, four days of fenceline boar exposure induced oestrus in 22% of group-housed lactating sows and 8.3% of individually housed lactating sows. This is markedly lower than the incidence of lactation oestrus previously reported in group housed sows, when fenceline boar exposure commenced 10 (81% lactation oestrus) or 7 (62% lactation) days prior to weaning at 28 days (Greenwood, 2016; van Wettere et al., 2017). It is also lower than incidences of lactation oestrus previously reported in response to reduced suckling regimes (interrupted suckling and split weaning) in conjunction with full or fence line boar exposure (reviewed by van Wettere et al., 2017). Based on the current findings, it is suggested that while daily fenceline boar exposure is an effective method of stimulating lactating sows to ovulate, it should start earlier relative to weaning in order to be most effective. Interestingly, a high proportion of Control and Crate+BE sows expressed oestrus within 5 days of weaning, suggesting that starting oestrus detection immediately after weaning may be necessary when sows lactate for 28 days. Based on these data it also appears that fenceline boar exposure during the last four days of lactation reduced the proportion of sows expressing oestrus within 5 days of weaning, but did not affect the proportion in oestrus after day 5. It is, therefore, suggested that sows with a propensity to express oestrus rapidly after weaning are more likely to come into heat whilst lactating when provided the correct stimulus (i.e. boar exposure).

It is interesting, and potentially significant from a production perspective, that a considerable proportion of sows which failed to display oestrus between day -4 to day +7 relative to weaning had circulating progesterone levels indicative of having ovulated between 4 and 15 days prior to day 7 (i.e. > 4 ng/ml). Assuming, these elevated progesterone levels were indicative of ovulation, then the incidence of undetected ovulation was 11.3%, 9.9% and 7.3% in the Control, Crate+BE and Group+BE treatments, respectively. It seems likely, that these sows would have ovulated (undetected) prior to weaning. Failure to detect oestrus in this population of sows has implication for litters produced per sow year and efficiency of the breeding herd.

Mating of sows during lactation, in the absence of any reduction or temporary prevention of suckling, commonly reduces sow fertility and fecundity (reviewed by van Wettere et al., 2017). This is supported by the current evidence, that mating sows in lactation decreased subsequent farrowing rate from 87% to 67%, and reduced subsequent total born and born alive by 1.3 and 1.0 piglets, respectively. Based on the current data, and the literature, it is suggested that a reduction in metabolic demand for milk production may be essential if the reproductive output of sows mated during lactation is to match that of those mated post-weaning (van Wettere et al., 2018).

Although not a primary objective of the study, the effects of gestation length on litter size and piglet survival were also analysed. Published data on Australian herds is sparse (non-existent); however, the current and previous unpublished data demonstrate that short pregnancies (< 115 days) result in more stillborn piglets (van Wettere, unpublished) and higher piglet mortality prior to fostering and weaning. This is consistent with European, Japanese and South American studies, in which short pregnancies were associated with increased stillbirth and pre-weaning mortality (Vanderhaughe et al., 2011; Mota-Rojas et al., 2015). This increase in intra- and post-partum mortalities is due to reduced piglet maturity at onset of parturition (Zaleski and Hacker, 1993) and longer farrowing durations (van Dijk et al., 2005). Further, piglets born alive to sows which farrowed experienced an increased severity of intra-partum oxygen deprivation and grew slower to weaning (Mota-Rojas et al., 2015). It may, therefore, be that cervical dilation may be impaired in sows which farrow prematurely, effectively increasing the strength and number of contractions experienced by the piglet prior to expulsion. Similar to previous data sets, a total 14% of sows and litters farrowed before day 115 of pregnancy, these animals lost on average 0.25 of a piglet more per litter prior to fostering. For a 1,000 sows breeding unit producing 2.4 litters per sow per year, this represents a loss of approximately 600 piglets per year in excess of animals with a normal (115 – 116 day) pregnancy. Given the association between earlier farrowing and developmental maturity, it might also be interesting to see how pigs from these animals fared after weaning. Recent evidence (Langendijk et al., 2018) demonstrated reduced growth to 10 weeks of age in piglets that were compromised during parturition. In this study, there was a significant correlation between pregnancy length prior to treatment and after treatment, and based on a data set from 140 farms and 13,715 farrowing records, Sasaki and Koketsu (2007) also reported high repeatability in pregnancy length within individual sows. Commercially, this is an interesting outcome as it emphasizes the need to focus more attention on the management of early born piglets and the need to develop strategies to prevent premature farrowing. Of particular concern would be batch-farrowing systems as the options to cross foster these potentially more vulnerable piglets are reduced due to lack of available foster sows.

5. Conclusion

Providing sows with fenceline boar exposure for four days prior to weaning increased the incidence of sows expressing oestrus during lactation, particularly when sows were housed in groups for the last seven days of lactation. However, contrary to the proposed hypothesis, fenceline boar exposure did not increase the reproductive output of sows which were mated post-weaning. Consistent with previous studies with the current and other genotypes, sows which were mated during lactation had lower farrowing rate and subsequent litter sizes than those which were mated post-weaning. These data indicate that mating sows during lactation, without reducing metabolic output for milk production, is not a viable option for the pig industry. The second component of this study was to evaluate the use of vulval temperature as a means of detecting spontaneous oestrus in lactating sows. Although vulval temperature did increase at oestrus, its value as a strategy to detect lactation oestrus could not be confirmed due to the low incidence of lactation oestrus in this study. Finally, it is evident from the current study, as well as previous Australian and European studies that sows with short pregnancies give birth to less viable piglets and/or are more likely to experience difficult parturitions, both of which result in more intra- and post-partum piglet deaths.

6. Limitations/Risks

The limitation from this body of work is that the results are derived from one genotype. There is inherent variation between genotypes in their ability to respond to lactation oestrus stimulation protocols and, therefore, future work in other genotypes could be appropriate. The biggest limitation to the data is the lack of a group lactation treatment in which sows did not receive boar stimulation. Therefore, it remains unclear whether lactation oestrus was stimulated or whether the presence of the boar facilitated detection of spontaneous ovulators.

7. Recommendations

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

- Fenceline boar exposure during the last 4 days of gestation did not improve fertility of sows mated post-weaning
- Future work should be conducted to further validate the potential benefits of using thermal imagery to detect spontaneous ovulation during lactation
- The relatively high incidence of sows which ovulated silently, and thus were mated at their second post-partum oestrus should be investigated further
- The impact of short pregnancy lengths on piglet survival and growth from birth to slaughter should be investigated, and strategies to prevent short pregnancies (premature farrowings) should be investigated.
- The apparent repeatability of gestation length within individual sows requires further investigation, as it may provide a useful tool for either strategic culling of sows or targeted use of interventions which prevent premature farrowing.

8. References

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Appendix 1 - Notes

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Appendices

Appendix 1: