STRATEGIES TO ENHANCE OESTRUS INDUCTION IN LACTATING SOWS
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Report prepared for the Co-operative Research Centre for High Integrity Australian Pork

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Executive Summary

The Australian pork industry has committed to the introduction of production systems that eliminate the use of sow confinement. The effective mating of sows in lactation can form the basis for an entirely new reproductive management paradigm that improves welfare and production efficiency without the need for sow confinement. There can be benefits for the litter by extending lactation without reducing the number of pigs weaned per sow per year. Results from an earlier Pork CRC project 2D-113 'Induction of oestrus in lactating sows' confirmed that under commercial conditions, it was possible to induce oestrus in lactating sows at 24-25 days after farrowing with an injection of PG600 at 20 days post-partum combined with fenceline boar exposure and overnight (16 h) piglet separation each day until mating by AI. The induction protocol was formulated from first principles and the significance of the individual elements was not known. Following on from this original success, the Pork CRC funded the current project with the overall objective being to refine the original protocol and identify the minimal strategy needed for successful induction of oestrus and mating in lactation.

The project consisted of four experiments which indentified the limit to when oestrus induction could be initiated in lactation, the role of PG600, the degree of piglet separation needed, the influence that fenceline boar exposure has and the extent of spontaneous ovulation in lactating sows.

Sows can be induced to display oestrus as early as day 14 of lactation although day 16 is more likely the earliest limit for successful farrowing rates and subsequent litter size. Successful rates of lactational oestrus induction are possible without the use of PG600 although it may act to guarantee an appropriate success under a range of commercial constraints and to achieving good litter outcomes. For successful oestrus induction from day 17 of lactation, the extent of piglet separation can be reduced to 16h for 3 days. At the same time in lactation, an 8h period of piglet separation for 3 days supports the induction of oestrus but there remain reservations, with possible negative effects on farrowing rate and litter size. Fenceline boar exposure alone was not a sufficient stimulus to induce oestrus in a high percentage of lactating sows. This manner of boar exposure resulted in some sows showing standing oestrus but failing to ovulate. The use of direct contact boar exposure alone might increase the percentage of sows responding but successful pregnancy rates and litter size might require the use of some exogenous gonadotrophic support.

An essential finding of this project was the extent of spontaneous ovulation in lactating sows. For the genotype used here, around 15% of sows had spontaneously ovulated during lactation. This has major implications for any lactational oestrus induction protocol and also for the conventional dogma that sows need to be weaned before they will return to oestrus.

The project has refined the original oestrus induction protocol with separation being the key element of the original protocol. The extent of separation is currently set at 3 days for 16 h but further refinements to 8h/d could be possible if induction in initiated later in lactation, say on day 20. Modern genotypes seem to be responsive to oestrus induction during lactation with minimal intervention. This is supported by the extent of spontaneous ovulation observed in commercial sows. In light of this being confirmed, conventional sow management needs to be reviewed and modified to prevent long weaning to oestrus intervals that add to sow culling rates and the high sow wastage seen in Australian pig herds.

There is the need for further research to continue the refinement of the induction protocol and to establish a strategy that works in a range of commercial environments including group lactational housing systems.

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1. Introduction

A central element of sow reproductive management is the need to wean the litter for the sow to return to oestrus and be re-mated. This has promoted producers to reduce the lactation length with the objective of maximizing the number of litters/sow/year; a factor with significant relevance to economic success. The need to wean sows and piglets before re-mating is based on the general acceptance that sows are anoestrus during lactation (Armstrong *et al.*, 1988). However, abrupt early weaning creates significant issues for piglets and requires considerable attention to management during the post-weaning period (review: van Beers-Schreurs *et al.*, 1992). A common consequence of weaning is a reduction in feed intake in piglets with the dramatic change from a milk diet to a dry, cereal based diet. This condition, often referred to as 'weaner set-back', has a major affect on smaller piglets and is associated with an increase in disease incidence and widespread use of in-feed antibiotics in weaner diets.

If it were possible to consistently induce oestrus during lactation, the sow could be mated at three weeks after farrowing but weaning could be delayed. This strategy would be expected to reduce the incidence of weaner 'set-back', reduce antibiotic use and help to limit the variation in market live weight.

The failure of ovarian follicles to develop to the pre-ovulatory stage is the essential reason for lactational anoestrus (Armstrong *et al.*, 1988). Pre-ovulatory follicle development fails in lactation because the LH support needed is not sufficient. During lactation the LH pulse frequency is too low to support the final stages of follicle development needed for ovulation (Cox and Britt, 1982; Shaw and Foxcroft, 1985). As lactation progresses there is a gradual increase in the LH pulse frequency as the hypothalamic-pituitary-axis becomes less response to suckling inhibition and the suckling frequency is reduced (Britt *et al.*, 1985). If the piglets are left with the sow sufficiently long enough eventually they gradually wean themselves and the sow will display oestrus and ovulate.

The inhibition of LH release is related to the suckling stimulus of the piglets (De Rensis et al., 1999) but is also influence by other factors such as sow metabolic state and parity (Prunier *et al.*, 2003). A catabolic state induced in lactation will reduce LH secretion (Zak *et al.*, 1998). Reducing the suckling stimulus will increase LH release (Varley and Foxcroft, 1990). This can be achieved by removing some piglets (split weaning: reviewed by Matte, *et al.*, 1992) or limiting the amount of time sows and piglets spend together, often referred to as intermittent suckling (reviewed by Langendik, *et al.*, 2007), but is probably better identified as restricted suckling because with most intermittent suckling regimes the time sows and piglets are separated each day is fixed.

The concept of oestrus induction during lactation is not new. This idea was first proposed over 55 years ago by Cole and Hughes (1946) and further investigated by Heitman and Cole (1956), Hausler *et al.* (1980) and Hodson *et al.* (1981). These efforts (reviewed by Britt *et al.*, 1985) used a combination of pregnant mare serum gonadotrophin (PMSG) at 2-3 weeks after farrowing to stimulate follicle development followed by human chorionic gonadotrophin (hCG) to induce ovulation. However, this strategy was unsuccessful because the application of PMSG resulted in the presence of only small follicles when the hCG was given.

The oestrus induction protocols involving piglet and sow separation varied greatly as did the degree of success. Twelve hours of separation for 25 days starting on day 10 of lactation resulted in 3% lactational oestrus (Henderson and Hughes, 1984). Starting on day 20 of lactation, twelve hours of separation for 10 days had no effect (Cole et al., 1972). While a 6 h separation period for 8 days starting on day 20 of lactation was 100% successful (Newton, 1987b). There are other published data but in essence there are three components of these induction protocols which will influence the degree of suckling stimulus, the daily piglet separation time (h), the period of separation (days) and the day of lactation at which the protocol is initiated. In addition to these influences, other sow based aspects are also likely to influence the success of any induction protocol. These would included parity (primiparous Vs multiparous), sow metabolic state (Clowes et al., 2003; Vinsky *et al*., 2006; Foxcroft *et al*., 2009; Schenkel *et al*., 2010; Patterson, *et al*., 2011), genotype (Gerristen, 2008), boar exposure (Petchey and Jolly, 1979; Newton *et al*., 1987a and b; Costa and Varely, 1995; Mota, *et al*., 2002; Downing *et al*., 2007, 2009; Kongsted and Hermansen, 2009), group housing (Rowlinson and Bryant, 1981, 1982; Hulten, et al., 1998, 2006) and stress.

Lactational oestrus induction has the potential to:

1. Uncouple weaning from re-mating of the sow and allow transference of the mating management to the farrowing accommodation.

2. Provide new opportunities to support management changes linked to the industry's commitment to remove sows from gestation stalls and investigate the use of confinement free farrowing accommodation.

3. Reduce non-productive days in the breeding herd. The extent of this will depend on the weaning age and when induction is initiated.

4. Provides increased flexibility as when to wean without compromising the number of litters per sow per year and would support gradual weaning.

5. Increase weaning age will reduce the potential risk of post-weaning diarrhoea and the need to treat piglets with antibiotics.

Results from Pork CRC project 2D-113 'Induction of oestrus in lactating sows' confirmed it was possible to induce oestrus in lactating sows at 24-25 days after farrowing with an injection of PG 600 (400 IU PMSG and 200 IU hCG: Intervet, Australia Pty. ltd) at 20 days post-partum combined with boar exposure and overnight (16 h) piglet separation each day until mating by AI. The piglet separation was achieved by placing piglets in adjacent vacated farrowing pens. The boar exposure consisted of moving the boar along the lane in front of the farrowing crates and holding him in front of each sow while oestrus was checked for. When compared with a cohort of sows weaned conventionally at day 20 of lactation, there was no measurable difference in mating times (both groups averaging 4.5 days) or subsequent farrowing performance.

The induction protocol was formulated from basic principles:

(i) The PG600 (400 IU PMSG and 200 IU hCG: Intervet, Australia Pty. ltd) was provided to ensure adequate healthy ovarian follicles where at the right stage to respond the endocrine changes initiated by piglet separation.

(ii) The piglet separation was instigated to disrupt the suckling for part of the day and combined with boar exposure was designed to provide sufficient LH secretion to support pre-ovulatory follicle development.
(iii) Boar exposure provided assistance with oestrus detection and potentially enhance oestrus stimulation in sows.

The protocol in its original format was successful but there remained no clear understanding of the relevance of each of the components. There was a need to determine the significance of each component and also to refine aspects of the protocol in an effort to determine the minimal requirements for successful oestrus induction. These overall requirements formed the basis of the current project.

Objectives of the project proposal:

1. To investigate the effect of injecting PG600 earlier than 20 days post-partum, combined with boar exposure and piglet separation (1600-0800 h) each day until mating, on oestrus induction and subsequent reproductive performance in multiparous sows.
2. To examine the effect of reducing the timing (number of days) of piglet separation on oestrus induction and subsequent reproductive performance.
3. To assess the effect of reducing the duration (hours per day) of piglet separation on oestrus induction and subsequent reproductive performance.
4. To conduct a commercial evaluation study of the best oestrus induction strategy from objectives 1 to 3 and compare this with conventional industry weaning practice.

The first three objectives remained central to the project but there were developments at the research facility that prevented the undertaking of objective 4. This objective was replaced with the following:

To investigate aspects of natural oestrus occurrence in sows with the potential to develop procedures for oestrus induction that don't required piglet separation.

2. Methodology

2.1. General methods

All experiments were conducted at the Research and Innovation unit of Rivalea Pty. Ltd., Corowa, NSW, Australia. Farrowing is conducted weekly with 64 sows housed in each farrowing unit. Of these approximately 40 sows are multiparious and 24 primiparpous. Therefore, to achieve sufficient treatment numbers the experiments were undertaken in consecutive weeks. All studies were approved by the Animal Care and Ethics Committee of Rivalea Pty. Ltd., and complied with the Australian Code of Practice for the use of Animals for Scientific Purposes.

2.1.1. Animals and maintenance

In all experiments Large White X Landrace (PrimeGro^{Tm} Genetics) F1 sows were used. The sows were moved to conventional farrowing crates at around 112 days of gestation and maintained there until weaning which average day 26 of lactation. Each sow had voluntary access to water and a commercial lactating sow diet formulated to contain 14.7MJ digestible energy and 19% protein.

Where appropriate, piglet separation was achieved in the farrowing crate by placing a board between the sow and piglet on one side of the farrowing crate. Piglets were provided with supplementary heating and had access to a nipple drinker and from the time of separation were supplied with creep feed formulated to supply 15.5MJ digestible energy and 21.7% protein.

2.1.2. Experiment 1. Earliest limit to the induction of oestrus in lactating sows

2.1.2.1. Experimental design

A total of 115 multiparous sows from three consecutive farrowing weeks (3 replicates) were used in this experiment. Full lifetime reproductive performance was known for all sows. The sows were allocated to treatment groups based on parity and suckling litter size. Within parity and litter size groupings the allocation to treatment groups was random.

The treatment groups were:

- (i) Control – with boar exposure only
- (ii) Sows given a PG600 injection on day 14 of lactation with piglet separation and boar exposure until mating
- (iii) Sows given a PG600 injection on day 16 of lactation with piglet separation and boar exposure until mating
- (iv) Sows given a PG600 injection on day 18 of lactation with piglet separation and boar exposure until mating

The PG 600 injection was given at 08:00 h and piglet separation started at 15:30 h on the same day. Piglets were returned to the sow at 07:30 h the next morning and separation continued until oestrus detection and mating or until a maximum of 7 days after the PG600 injection. Boar exposure consisted of walking the boar around the laneway in front of the farrowing crates and holding him in front of each sow to encourage nose to nose contact while oestrus was checked for using the back pressure test. Because boar exposure started at day 14 for treatment group two, all sows in the farrowing unit were exposed to the boar from this time. All sows in any replicate were weaned on the same day which was an average of 26 ± 0.2 days of lactation but did vary from 22 to 32 days of lactation because of differences in farrowing date. Sows where pregnancy tested using real time ultrasound diagnosis at an average of day 40 post mating. Each litter, was weighed on day 14 and day 23 of age.

2.1.2.2. Statistical analysis

Data was stored in Microsoft Excel®. The sow proportions mated in lactation and after weaning, the proportions not pregnant at day 40 and those which farrowed were analysed using a Chi square test or when a category contained less than five data points a Fishers exact test was used (R Version: The R foundation for statistical computing). When any treatment differences were significant, all pair wise comparisons were made using the same analysis with significance set at P<0.05.

The effects of parity and litter size suckled during the induction on treatment responses and the treatment effects on the time from induction to mating or days from weaning to mating were all analysed by ANOVA (Genstat V. 12). Where treatment differences were found to be significant (P<0.05) the individual comparisons of means were made using the least significant difference (LSD), which is equal to twice the standard error of differences (SED). Similarly, the effects of treatment, parity and sow average lifetime performance for total born and born alive, on the subsequent farrowing performance (litter size etc.) were analysed using ANOVA. The same ANOVA analysis was computed for the effects of treatment, parity, suckling litter size on the day 14 and 23 litter weights and the daily growth rate of piglets between days 14 and 23.

2.1.3. Experiment 2. The timing of piglet separation in relation to the PG 600 injection.

2.1.3.1. Experimental design

In this particular experiment, the role of PG 600 and the length of piglet separation (days) were evaluated. There was also the opportunity to test the original induction protocol in a group of primiparous sows.

A total of 121 multiparous and 30 primiparous sows from four consecutive farrowing weeks (4 replicates) were used in this experiment. It was planned to have 30 sows per treatment group but after removal of some sows for various production reasons the group sizes varied from 21 to 30. Full lifetime reproductive performance was known for all sows. The sows were allocated to treatment groups based on parity and suckling litter size. Within parity and litter size groupings, the allocation to treatment groups was random.

The treatment groups were:

- (i) Multiparous lactating sows injected with PG600 only and without any piglet separation.
- (ii) Multiparous lactating sows injected with PG600 and piglets separated from the sows for the first three nights only, after the injection.
- (iii) Multiparous lactating sows injected with PG600 and piglets separated from the sows starting on the third night after the injection until mating.
- (iv) Multiparous lactating sows having no PG600 injection and piglets separated from the sows from the time of injection until mating
- (v) Multiparous lactating sows without PG 600 injection or piglet separation (Control)
- (vi) Parity one lactating sows injected with PG600 and piglets separated from the sows from the time of injection until mating

The PG 600 injection was given at 08:00 h and where piglet separation was involved it started at 15:30 h on the day of injection for treatments 1, 2 and 6, on the third day after injection for treatment 3 and on the day of separation for treatment 4. Piglets were returned to the sow at 07:30 h the following morning. All sows were exposed to a mature boar and this consisted of walking the boar around the laneway in front of the farrowing crates and holding him in front of each sow to encourage nose to nose contact while oestrus was checked for by using the back pressure test. Boar exposure started on the day the first sows where treated and so all sows in a replicate were exposed to the boar from this time. All sows in any replicate were weaned on the same day which was on average 26.8 ± 0.2 days of lactation but this did vary from 22 to 32 days of lactation because of differences in farrowing date. Sows where pregnancy tested using real time ultrasound diagnosis at an average of day 40 post mating. Each litter, was weighed on day 14 and day 23 of age.

2.1.3.2. Statistical analysis

The sow proportions mated in lactation and after weaning, the proportions not pregnant at day 40 and those which farrowed were analysed using a Chi square test or when a category contained less than five data points a Fishers exact test was used (R Version: The R foundation for statistical computing). When any treatment differences were significant, all pair wise comparisons were made using the same analysis with significance set at P<0.05.

Parity, litter size being suckled during the induction and the days from farrowing until induction started for the treatments were analysed by ANOVA and were differences were significant individual comparisons were made using the least significant difference (LSD), which is equal to two times the standard error of differences (SED).

The effects of treatment, parity, sow average lifetime performance for total born and total born alive, on the subsequent total litter size, number born alive and numbers of still and mummified births were analysed using ANOVA. The analysis was conducted for the sows mated in lactation but the values from group 5 sows were excluded because of the small number of sows in this group. For sows mated after weaning the only comparison was made between group 1 and 5 as the treatment number were too low in the other groups. A further analysis was made by comparing sows of groups 1 to 4 and 6 that had been mated in lactation with those sows from group 5 mated after weaning. Where effects were significant individual comparisons were made using the least significant difference (LSD).

The effects of treatment, parity and suckling litter size on day 14 and 23 weights and the daily growth rate between days 14 and 23 were analysed again by ANOVA and again when differences were significant the individual differences were tested by LSD as described above.

2.1.4. Experiment 3. Duration of piglet separation.

This experiment was a continuation of the overall objective of the project to refine the oestrus induction protocol. In this particular experiment, a specific objective was to determine whether the response to induction at around day 18 of lactation differs when piglets are separated from the sow over three consecutive days for either 8 hours during the day, or 16 hours overnight. Secondly, the effectiveness of oestrus induction without PG600 when litters are separated for only 3 days overnight was also evaluated.

2.1.4.1. Experimental design

A total of 115 multiparous sows from three consecutive farrowing weeks (3 replicates) were used in this experiment. Full lifetime reproductive performance was known for all sows. The sows were allocated to treatment groups based on parity and suckling litter size. Within parity and litter size groupings the allocation to treatment group was random. A further treatment group was included where induction (3 days with 16 h of piglet separation) was initiated at day 21 of lactation. In this group it was anticipated that the sows would be mated just prior weaning.

The treatment groups were:

(i) Multiparous lactating sows with no PG600 injection and piglets separated for 3 days of 16h/d starting on a day 18 of lactation

(ii) Multiparous lactating injected with PG600 and piglets separated for 3 days of 16h/d starting on day 18 of lactation

(iii) Multiparous lactating injected with PG600 and piglets separated for 3 days of 8h/d starting at day 18 of lactation

(iv) Multiparous lactating injected with PG600 and piglets separated for 3 days of 16h/d starting on day 21 of lactation

The PG 600 injection was given at 08:00 h and where piglet separation was for 16 h/d it started at 15:30 h, with piglets returned to the sow at 07:30 h the next day. Where the piglet separation was for 8 h/d it started at 07:30 h, with piglets being returned to the sow at 15:30 h the same day. On average the treatments were designed to commence on either day 18 or day 21 of lactation. All sows were exposed to a mature boar and this consisted of walking the boar around the lane in front of the farrowing crates and holding him in front of each sow to encourage nose to nose contact while oestrus was checked for by using the back pressure test. Boar exposure started the day the first sows were treated and so all sows in a replicate were exposed to the boar from this time even if they had not actually started their full treatment. All sows in any replicate were weaned on the same day which was an average of 26.4 ± 0.1 days of lactation for groups 1-3 but this did vary from 24 to 31 days of lactation because of differences in farrowing time. For group 4 sows weaning averaged 28.4 ± 0.3 days of lactation but this did vary from 25 to 31 days of lactation because of differences in farrowing time. Sows where pregnancy tested using real time ultrasound diagnosis at an average of day 40 post mating. Each litter was weighed on day 14 and day 23 of age.

2.1.4.2. Statistical analysis

Data was stored in Microsoft Excel®. The sow proportions mated in lactation and after weaning, the proportions not pregnant at day 40 and those which farrowed were analysed were analysed using a Chi square test or when a category contained less than five data points a Fishers exact test was used (R Version: The R foundation for statistical computing). When any treatment differences were significant, all pair wise comparisons were made using the same analysis with significance set at $P<0.05$.

The effects of parity and litter size suckled during the induction on treatment responses and the treatment effects on the time from induction to mating or days from weaning to mating were all analysed by ANOVA (Genstat. V12). Similarly, the effects of treatment, parity and sow average lifetime performance total born and born alive, on the subsequent farrowing performance (litter size etc.) were analysed using ANOVA. Where differences were found to be significant ($P<0.05$) the individual comparisons of means were made using the least significant difference (LSD), which is equal to twice the standard error of differences (SED).

The effects of treatment, day of lactation treatments were initiated, parity and suckling litter size on day 14 and 23 litter weights and the daily growth rate between days 14 and 23 were analysed again by ANOVA and when differences were significant the individual differences were tested by LSD as described above.

2.1.5. Experiment 4: Spontaneous ovulation occurrence and oestrus induction in commercial lactating sows, using boar exposure alone or after gonadotropin treatment at farrowing.

2.1.5.1. Introduction

Following on from the results of the three earlier studies, the following questions became relevant to the lactational oestrus induction protocol;

1. What is the extent of spontaneous ovulation in the lactating sows?
2. What effect does fenceline boar contact have on the rate of oestrus induction during lactation?
3. What are the physiological mechanisms associated with spontaneous ovulation?

The objectives of this experiment were:

1. To determine the extent of natural oestrus in lactating sows.
2. Identify the influence fenceline boar exposure may have had on oestrus induction in lactating sows.
3. Investigate the role that early post farrowing ovulation could have on oestrus induction later in lactation.

2.1.5.2. Experimental design

A total of 244 sows, over four consecutive farrowing weeks were used in the experiment. On day 112 of gestation, the mixed parity sows were transferred from the dry sow facility to individual crates in the farrowing shed. After farrowing the sows were gradually introduced to a lactational diet and by 7 days fed to appetite by supplying fresh feed three times daily, for the duration of the study.

The treatment groups were:

Group A - control untreated sows: These sows farrowed in weeks 1 and 4. They farrowed as normal and were subjected to the general managements procedures applied at Rivalea Pty Ltd. The piglets were weaned at an average age of 29 days for farrowing 1 and on an average of day 25 for farrowing 4. All sows were culled 4 days after weaning and the ovaries collected and examined.

Group B – Sows were treated with gonadotrophins at farrowing and fenceline boar exposure: These sows farrowed in weeks 2 and 3. Sows received an intramuscular injection of 1000 IU of Pregnant Mare Serum Gonadotropin (PMSG: Folligon: Intervet Australia Pty. ltd) at 0800h on the day of farrowing. This was followed by an intramuscular injection of 750 IU of Human Chorionic Gonadotropin (hCG: Chorulon: Intervet Australia Pty. ltd) 76 hours after the PSMG. Sows were exposed to a mature boar twice daily from around day 15 of lactation until weaning.

Group C – Sows with fenceline boar exposure only: These sows farrowed in weeks 2 and 3. The sows were exposed to a mature boar twice daily, from around day 15 of lactation until weaning without any gonadotrophin treatment.

Sows allocated to groups B and C were housed in the same farrowing houses over two consecutive weeks of farrowing. As the sows farrowed they were alternatively allocated to group B or C. The boar exposure (both in the morning and afternoon) consisted of moving the boar around the laneway, in front of the farrowing crates and holding him in front of each sow to encourage nose to nose contact while oestrus was checked for using the back pressure test. The piglets were weaned at an average age of 29 days and sows were culled 4 days after weaning and the ovaries collected and examined.

On an average of day 14 of lactation a 10 mL blood sample was collected from all treatment B and C sows. These blood samples were centrifuged, and the plasma collected and frozen at -4^{o}C until analysis of progesterone concentration using a validated radioimmunoassay (Downing et al., 1995).

At weaning all sows were body tattooed for identification. Four days after weaning sows were processed at a commercial abattoir. Both ovaries were collected and then assessed visually for presence of corpora lutea (CL), corpora albicans (CA), large follicles (>3mm), small follicles, (<3mm) and any cystic follicles.

2.1.5.3. Statistical analysis

For the statistical analysis, data were transferred into an Excel file and checked for any outliers or missing data. Subsequently, the statistical program SPSS 17.0 was used to analyse the data and for continuous variables, the data were checked for a normal distribution (KS-test; P-value >0.20) and if a non normal distribution existed the data were transformed on an appropriate scale.

For the analysis, firstly, the descriptive data was determined for average litter size, proportion of sows which expressed lactational oestrus, number of follicles, corpus lutea, corpus albicans and/or cystic follicles found on the ovaries collected at the abattoir. An ANOVA analysis was used to compared the continuous variables for which a P-value <0.05 was considered as the threshold for a significant difference and a P-value <0.10 as being a trend. Binary measures were analyzed using a Chi square test or when a category contained less than five data points a Fishers exact test was used. Again the P values of <0.05 and <0.10 were used to determine if there was a significant difference or a trend between treatment groups.

A two way ANOVA was used to compare if litter size, number born alive, mummies and number weaned was different between the three treatment groups (controlled for parity). In addition to this, a survival analysis (Kaplan Meier with Log Rank test) was used to examine a difference between treatment B and C when sows expressed lactational oestrus over time. Finally, Chi square test was used to examine if there were any significant differences in proportions of lactational oestrus, and finding corpus lutea on the ovaries' between the two repetitions within the trial.

3. Outcomes

3.1.1. Study 1. Earliest limit to the induction of oestrus in lactating sows

The mating performance of the treated sows is given in Table 1. The mean parity age was similar for treatments (P=0.96) and the suckling litter size during the induction period was not different (P=0.07), although it tended to be larger for sows induced on day 18 of lactation.

Treatment	Control	Induction day			P value
		14	16	18	
Sows treated	29	29	28	29	-
Average parity	3.5 ± 0.2	3.5 ± 0.3	3.7 ± 0.3	3.6 ± 0.2	0.96
Average litter size suckled in lactation	8.5 ± 0.4	8.4 ± 0.4	8.1 ± 0.4	9.6 ± 0.4	0.07
% mated in lactation (number)	20.7^{b} (6)	79.3^{a} (23)	92.9^{a} (26)	89.7^{a} (26)	<0.001
% mated after weaning (number)	79.3^{a} (23)	17.2^{b} (5)	7.1^{b} (2)	10.3^{b} (3)	<0.001
% Not mated (Number)	0	3.4 (1)	0	0	-
Total % of sows mated (Number)	100.0 (29)	96.5 (28)	100.0 (28)	100.0 (29)	-
Days from induction until mating	-	6.1 ± 0.1	5.9 ± 0.2	5.6 ± 0.2	0.15
Days in lactation sows mated	22.8 ± 0.9^{a}	19.2 ± 0.2^{c}	20.9 ± 0.3^{b}	22.5 ± 0.2^{a}	<0.001
Days from weaning until mating	5.0 ± 0.3^{b}	8.2 ± 1.1^{a}	5.5 ± 0.1^{ab}	7.1 ± 1.5^{ab}	0.02
Potential sows that could farrow	29	28	28	29	-

Table 1: The mating outcomes of sows following initiation of the oestrus induction protocol at day 14, 16 or 18 of lactation. Within a row, values with different superscripts are significantly different (P<0.05).

The percentage of sows mated in lactation was higher for all inducted groups compared to controls (P<0.05) but there was no effect of when in lactation the induction was started. Treatment had a significant effect on the percentage of sows mated after weaning (P<0.001) with it being greater for the control sows compared to the induced treatments (P<0.05). The time from induction until sows were mated was not influenced by day of lactation that induction was started (P=0.15). The weaning to oestrus interval was shorter in the control sows than those treated sows mated after weaning (P<0.05). However, the number of treated sows mated after weaning was low. Parity had no significant effects (P=0.44) on the percentage of sows displaying oestrus during lactation.

Treatment	Control	Induction day 14	Induction day 16	Induction day 18	P value
Total mated	29	28	28	29	-
Sows culled prior to day 40	0	2	1	0	-
Total potentially pregnant	29	26	27	29	
% mated in lactation and NIP* at day 40 (number)[1]	50.0% (3/6)	28.6 (6/21)	12.0 (3/25)	26.9 (7/26)	0.18
% mated after weaning and NIP* at day 40 (number)[2]	17.4 (4/23)	0.0 (0/5)	0.0 (0/2)	0.0 (0/3)	1.00
Total number pregnant (at day 40)[3]	75.9 (22/29)	76.9 (20/26)	88.9 (24/27)	75.9 (22/29)	0.55
Pregnancy failure after day 40	2	2	1	2	-
% mated in lactation and farrowed[1] (Number)	50.0 (3/6)	71.4 (15/21)	84.6 (22/26)	69.2 (18/26)	0.31
% mated after weaning and farrowed[2] (Number)	79.3 (17/23)	60.0 (3/5)	50.0 (1/2)	66.6 (2/3)	0.48
Total % sows farrowed[3] (Number)	69.0 (20/29)	64.3 (18/26)	82.1 (23/27)	69.0 (20/29)	0.41

Table 2: The pregnancy outcomes of sows following initiation of the oestrus induction protocol at day 14, 16 or 18 of lactation. Within a row, values with different superscripts are significantly different (P<0.05).

*NIP – Not in pig –Sows that returned to oestrus or where not pregnant
[1]Calculated as the % NIP of those mated in lactation
[2]Calculated as the % NIP of those mated in lactation
[3]Calculated as the % pregnant of the number mated

The pregnancy outcomes are given in table 2. The percentage of a sows mated in lactation and returning to oestrus or not pregnant at day 40 (P=0.18) or the percentage sow mated after weaning and returning to oestrus or not pregnant at day 40 (P=0.48) were not different between treatments. The percentage of sows that farrowed of those mated in lactation was not different between treatments (P=0.31) as was the percentage sows farrowing that had been mated after weaning (P=0.48).

The subsquent farrowing performance of sows resulting from the treatment matings are given in table 3. Treatment had no significant effects on total number born (P=0.18),number born alive (P=0.23), stillborn (P=0.44) or born mumified (P=0.32). Further analysis indicated that parity, the sow average lifetime performance for total litter number born and number born alive had no significant effects on any of the litter measures.

		Induction day			
Treatment	Control	14	16	18	P value
Total Born	13.30 ± 0.53	11.00 ± 0.62	12.24 ± 0.69	12.05 ± 0.56	0.18
Born alive	12.4 ± 0.8	10.2 ± 0.9	10.9 ± 0.8	11.7 ± 0.9	0.23
Still born	0.80 ± 0.24	0.56 ± 0.17	1.05 ± 0.23	0.56 ± 0.26	0.44
Mummified	0.05 ± 0.04	0.25 ± 0.08	0.29 ± 0.87	0.25 ± 0.10	0.32

Table 3: The farrowing performance of sows following initiation of the oestrus induction protocol at day 14, 16 or 18 of lactation.

Treatment	Control	Induction day			P value
		14	16	18	
Average 14-day piglet weight (kg)	4.38 ± 0.16	4.71 ± 0.13	4.56 ± 0.19	4.31 ± 0.17	0.32
Average 23-day piglet weight (kg)	6.43 ± 0.20^{a}	5.67 ± 0.12^{a}	5.51 ± 0.21^{a}	5.57 ± 0.20^{a}	0.002
Average piglet daily gain day 14-23 (g)	230 ± 11^{a}	122 ± 14^{b}	112 ± 12^{b}	127 ± 15^{b}	<0.001

Table 4: The growth performance of piglets suckling sows subjected to the oestrus induction protocol at day 14, 16 or 18 of lactation.

Treatment (P=0.32), parity (0.68) and suckling litter number (P=0.49), all had no effects on the day 14 litter weight. Parity (P=0.09) and suckling litter number (P=0.78), had no effects on day 23 litter weight but the treatment effect was significant (P=0.002). The litter weight for the control sows was significantly greater (P<0.05), than for the treatments where piglets were separated from the sows during lactation. These day 23 differences resulted in a significant (P<0.001) effect on daily rate of gain between days 14 and 23 with it being superior for the piglets from control sows (P<0.05). Parity (P=0.25) and litter suckling number (P=0.41) had no effects on daily rate of gain.

Summary:

1. Oestrus induction could be initiated as early as day 14 of lactation but there were non-significant trends in return to oestrus and litter size which requires caution in suggesting that induction start this early.
2. We propose that induction could be successful if initated from day 16 of lacation and thereafter.
3. Induction on day 16 and 18 resulted in 93 and 90% of sows having an oestrus and being mated during lactation, respectively.
4. For the day 16 treatment, the return the oestrus rate was low and 85% of the sows mated in lactation farrowed. The percentage farrowing rate for the day 18 and 14 treatmented sows mated in lactation was not significantly different at around 70%. However, the day 16 result suggests that 85% farrowing rate is feasible with lactational oestrus induction.
5. There was 20.1% of the control sows which were mated in lactation. This initially suggests that the boar contact alone was suffiicient to induce oestrus. However, casual observations during the trial indicated that some sows were probably spontaneously ovulating.
6. Of interest was the finding that the combination of mating in lactation or within 5-6 days of weaning resulted in 100% mating for all treatment groups. This would seem to

provide further support that spontaneous ovulation occurs in lactation and could account for the <100% mating that is normally achieved with conventional weaning.

7. While not significant with the sow numbers that farrowed, there would appear to be a poosible trend for the litter size to be lower in the induced treaments. This would need to be further considered once an induction protocol is fianlised and tested in a large commercial trial.
8. Separation of the piglets from the start of induction until mating had an adverse effect on piglet growth rate. A reduction in total separation time would help reduce any adverse effects.

3.1.2. Experiment 2. The timing of piglet separation in relation to the PG600 injection.

The mating outcomes are given in table 5. It was planned to have group sizes of 30 sows per treatment but there were a number of management limitations which resulted in experimental groups sizes ranging from 21 to 29, even after running 4 replicates per treatment. Treatments were started on an average of day 17 of lactation (see table 5), but ranged from day 15 to 20 for individual sows. There were no differences in average parity for experimental groups where multiparous sows were used. The suckling litter size was not different between treatments (P=0.23), with it being around 9 piglets per sow. The suckling litter size had no significant effect on whether a sow was mated in lactation or after weaning (P= 0.84).

The period from start of the treatment until mating was similar for all induction groups and was approximately 4-5 days. For the conventionally weaned control sows the weaning to mating interval was 4.5 ± 0.4 day and this was not different to the sows in the induction groups which failed to respond and were mated after weaning.

The percentage of sows displaying oestrus and mated in lactation that had been subjected to the induction protocols, ranged from 51.7% to 86.9%. There was a significant effect of treatment (P<0.001), on the percentage of sows mated in lactation with it being significantly higher for the treatment group where piglets had been separated from the sow for a period of time (P<0.05).

The percentage of sows displaying oestrus and mated after weaning that had been subjected to the induction protocols, ranged from 6.9% to 44.8%. There was a significant effect of treatment (P<0.001), with the percentage being significantly higher for the treatments group where piglets were not separated from the sow for a period of time (P<0.05). Across all treatments a total of 7 sows (6%) where not mated in lactation or within 7 days of weaning.

A similar percentage of primiparous sows treated with PG600 and having piglet separation (group 6) where mated in lactation as the multiparous sows receiving PG600 and piglet separation (groups 2 and 3), although the period of piglet separation used was longer for these first parity sows.

Sows treated with PG600 alone (group 1) had similar mating rates in lactation and after weaning as the control treated sows. Of interest, was the fact that 12 of the 26 (46.2%

Group	1	2	3	4	5	6	
Treatment	PG 600 and no SEP**	PG 600 + SEP* d 1-3	PG 600 + SEP* from d3-mating	No PG 600 +SEP* d1-matin	No PG 600 and no SEP*	PG 600 +SEP* d1-mating	P Value
Sow parity	Multi-					Prim-	
Sows treated	29	22	23	21	26	29	-
Parity	4.1 ± 0.3[a]	3.6 ± 0.3[a]	3.8 ± 0.4[a]	3.9 ± 0.3[a]	3.8 ± 0.3[a]	1.0[b]	<0.001
Average litter size suckled	9.5 ± 0.7	9.1 ± 0.3	8.7 ± 0.4	9.4 ± 0.3	9.0 ± 0.4	8.7 ± 0.3	0.23
Days to induction	17.3 ± 0.2	16.9 ± 0.2	17.1 ± 0.3	17.1 ± 0.4	-	16.9 ± 0.2	0.81
% mated in lactation[1] (Number)	51.7 (15)[b]	81.8 (18)[a]	86.9 (20)[a]	80.9 (17)[a]	30.8 (8)[b]	82.7 (24)[a]	<0.001
% mated after weaning (Number)[1]	44.8 (13)[a]	18.2 (4)[a]	8.7 (2)[b]	14.3 (3)[b]	50.0 (13)[a]	6.9 (2)[b]	<0.001
% displaying oestrus before weaning not mated (number)[1]	0	0	0	0	15.4[#] (4)	0	-
% sows not mated (Number)	3.4 (1)	0.0 (0)	4.3 (1)	4.8 (1)	3.8 (1)	10.3 (3)	-
Induction to mating (d)	3.7 ± 0.4	4.0 ± 0.4	4.7 ± 0.5	4.9 ± 0.3	-	4.2 ± 0.2	0.61
Weaning to mating (d)	5.33 ± 0.9	6.3 ± 3.0	4.5 ± 0.5	3.7 ± 1.3	4.5 ± 0.4	4.3 ± 0.7	0.87
Potential sows that could farrow	28	22	22	20	21	26	-

Table 5: The mating outcomes of sows following oestrus induction during lactation. Within a row values with different superscripts are significantly different (P<0.05).
*SEP- piglet separation
[#]Not mated because of a commercial management decision
[1]Analsys made on the proportion mated of the total mated

sows allocated to the conventionally weaned control group, having fenceline boar exposure but no PG 600 or piglet separation, displayed oestrus during lactation. Because of a commercial management decision only 8 of the 12 were actually mated in lactation.

The fact that close to half of the sows allocated to the conventionally weaned group displayed oestrus during lactation would suggest that limited fence line boar exposure alone is sufficient to induce oestrus. For control sows, 8 of the12 displayed oestrus 4-7 days after initial boar exposure suggesting that they might have responded to the boar. However, there can be no certainty that some of these sows had not spontaneously ovulated. While the boar is likely to have had some effect, it continued to be our belief, that a percentage of commercial sows undergo spontaneous ovulation during lactation independent of any boar stimulus.

If the boar exposure alone was acting as a stimulus, the current data would suggest that to get high mating rates it needs to be combined with some degree of piglet separation.

The similar lactation mating rates between the sows receiving PG600 and boar exposure only and the control conventionally weaned sows would indicate that PG600 alone has no substantial effect on the rate of oestrus induction. This is further supported by the high mating percentage observed for the treatment where multiparous sows had no PG600 but were mated after 4.9 ± 0.3 days of piglet separation.

The high mating percentage for sows separated from the piglets for the first three days after PG600 or from the third day after PG 600 until mating is important because it reduces the piglet separation time to 3 days. This has significant consequences for the practical implementation of oestrus induction in lactation and as discussed later, important consequences for piglet growth rate.

The pregnancy outcomes are given in table 6. The term not-in-pig (NIP) is used to identify sows returning to oestrus after mating or identified as not pregnant. The sows NIP before day 40 and after day 40 of gestation is given in table 6. Because the number of sows in some categories is small, the relevance of some comparisons needs to be made with this in mind.

The percentage of sows mated in lactation and NIP at day 40 was not different for treatments (P=0.84). However for the multiparous sows were there was no piglet separation (groups 1 and 5) 11 of 23 sows were NIP at day 40 while for the induction treatments with piglet separation (groups 1-34) 13/55 were NIP at day 40. A comparison of the proportions indicated that the difference was marginally non-significant (P=0.06). This point is highlight because it possible that fenceline boar exposure might encourage sows into oestrus but that the stimulus is not sufficient to promoted ovulation in some sows.

There was a tendency for treatment to have an effect on the percentage of sows farrowing that were mated in lactation (P=0.08). The percentage tended to higher in groups 2 and 3. A relevant comparison is between the percentage of control sows that farrowed and were mated after weaning with the percentage of induced sows that farrowed and had been mated in lactation. When individual comparisons are made then there is no differences between the control sows and those being treated with PG600 and separated for 3 days (groups 2 and 3) The difference between control sows and those multiparous (group 4; P=0.09)) or primiparous sows (group 6: P=0.06), with piglet separation for the longer period were marginally non-significant.

Group	1	2	3	4	5	6	
Treatment	**PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1-3**	**PG 600 with 'SEP' days 3 to mating**	**No PG 600 'SEP' day 1 to mating**	**No PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1 to mating**	**P Value**
Sow parity	Multi					Primi	
Potential sows pregnant of those treated	28/29	22/22	22/23	20/21	21/26	26/29	-
% mated in lactation and NIP* at day 40 (Number)[1]	53.3 (8/15)	22.2 (4/18)	20.0 (4/20)	29.4 (5/17)	37.5 (3/8)	29.2 (7/24)	0.84
% mated after weaning and NIP* day 40[2] (Number)[2]	23.1 (3/13)	50.0 (2/4)	50.0 (1/2)	0.0 (0/3)	7.7 (1/13)	50.0 (1/2)	0.20
% mated in lactation and NIP after day 40 (Number)[1]	6.7 (1/15)	0.0 (0/18)	0.0 (0/20)	11.8 (2/17)	25.0 (2/8)	8.3 (2/24)	0.12
% mated after weaning and NIP after day 40 (Number)[3]	6.7 (1/13)	0.0 (0/4)	50.0 (1/2)	0.0 (0/3)	0.0 (0/13)	50.0 (1/2)	-
% mated in lactation and farrowed (Number)[1]	40.0 (6/15)	77.8 (14/18)	80.0 (16/20)	58.8 (10/17)	37.5 (3/8)	62.5 (15/24)	0.08
% mated after weaning and farrowed (Number)[2]	69.2 (9/13)[a]	50.0 (2/4)[a]	0.0 (0/2)[b]	100.0 (3/3)[a]	92.3 (12/13)[a]	0.0 (0/2)[b]	0.01
Total % sows farrowed (Number)[4]	53.6 (15/28)	72.7 (16/22)	72.7 (16/22)	65.0 (13/20)	71.4 (15/21)	65.2** (15/23)	0.27

Table 6: The pregnancy outcomes of sows following oestrus induction during lactation. Within a row values with different superscripts are significantly different ($P<0.05$).

[1] % calculated relative to the number mated in lactation

[2] %calculated relative to the number mated after weaning

[3]No analysis made as the numbers are too low

[4] %calculated relative to the total number mated

*NIP – returned to oestrus or not pregnant

**Records of one sow mated after weaning lost so the mated number reduced to 23

Group	1	2	3	4	5	6	
Treatment	**PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1-3**	**PG 600 with 'SEP' days 3 to mating**	**No PG 600 'SEP' day 1 to mating**	**No PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1 to mating**	**P Value**
Sow parity	Multi					Primi	
All sows that farrowed							
Born alive	11.40 ± 0.70	11.50 ± 0.92	12.19 ± 0.59	11.00 ± 1.10	11.60 ± 0.83	11.80 ± 0.63	0.94
Stillbirths	0.53 ± 0.18	1.63 ± 0.42	0.88 ± 0.43	0.77± 0.47	0.80 ± 0.33	0.80 ± 0.42	0.13
Mummified	0.53 ± 0.27	0.19 ± 0.14	0.31 ± 0.18	0.08 ± 0.08	0.13 ± 0.09	0.20 ± 0.06	0.51
Total born	12.47 ± 0.83	13.31 ± 1.02	13.31 ± 0.66	11.85 ± 1.15	12.53 ± 0.94	12.80 ± 0.63	0.29
Sows farrowed that were mated in lactation							
Born alive	10.5 ± 1.2	11.8± 0.8	12.2 ± 0.7	12.4 ± 0.9	7.7 ± 1.7	11.80 ± 0.7	0.77*
Stillbirths	0.17 ± 0.67	1.64 ± 0.44	0.87 ± 0.41	1.00 ± 0.52	0.67 ± 0.94	0.80 ± 0.43	0.43*
Mummified	0.33± 0.21	0.07 ± 0.13	0.31 ± 0.13	0.10 ± 0.16	0	0.20 ± 0.13	0.67*
Total born	11.0 ± 1.3	13.50 ± 0.8	13.3 ± 0.8	13.5 ± 1.0	8.33 ± 1.8	12.8 ± 0.8	0.52*
Sow farrowed that were mated after weaning							
Born alive	12.12 ± 0.95	9.50 ± 0.50	Nil	6.33 ± 1.20	12.53± 0.71	Nil	0.81**
Stillbirths	0.87 ± 0.23	0.6 ± 0.4	Nil	0	0.83 ± 0.37	Nil	0.78**
Mummified	0.50 ± 0.38	1.0 ± 1.0	Nil	0	0.17 ± 0.11	Nil	0.12**
Total born	13.50 ± 1.07	12.0 ± 2.0	Nil	6.3 ± 1.20	13.58 ± 0.83	Nil	0.89**

Table 7: The subsequent farrowing performance for sows following oestrus induction during lactation. Values are given as mean ± SEM.
*Analysis excludes group 5 because of the low sample number.
** Analysis includes only groups 1 and 5 because of the low sample number in other groups.

The farrowing performances are given in table 7. When all sows are included, those mated in lactation and those mated after weaning, there were no significant treatment differences in total number born (P=0.29), number born alive (P =0.94), number of still born (P=0.13) or number of mummified piglets delivered (P=0.51).

When the farrowing performance is compared for only those sows mated in lactation from the induction treatment groups (excludes Group 5), there were no significant treatment effects on total litter size born (P=0.52), number born alive (P=0.77), number of stillbirths (0.43) or the number of mummified births (P=0.67). Sow parity had no effect on the total litter size (P=0.21), number born alive (P=0.15), number of stillbirths (0.93) or the number of mummified births (P=0.43). The sow lifetime average total number born had no effect on the total litter size (P=0.34), number born alive (P=0.40), number of stillbirths (0.24) or the number of mummified births (P=0.67). The sow lifetime average number born alive had no effect on the total litter size (P=0.50), number born alive (P=0.80), number of stillbirths (0.79) or the number of mummified births (P=0.12).

For the comparison between group 1 and 5 sows that were mated after weaning and subsequently went on to farrow, no significant treatment effects on total litter size (P=0.89), number born alive (P=0.81), number of stillbirths (0.78) or the number of mummified births (P=0.12). Sow parity had no effect on the total litter size (P=0.82), number born alive (P=0.70), number of stillbirths (0.42) or the number of mummified births (P=0.35). The sow lifetime average total number born had no effect on the total litter size (P=0.33), number born alive (P=0.17), number of stillbirths (0.19) or the number of mummified births (P=0.95). The sow lifetime average number born alive had no effect on the total litter size (P=0.99), number born alive (P=0.93), number of stillbirths (0.16) or the number of mummified births (P=0.94).

An important comparison is between the sows mated in lactation for the induction treatments with those control (Group 5) sows mated after weaning. When this comparison is made there were no differences in total number born (P=0.65), number born alive (P =0.83), number of still births (P=0.53) or number of mummified piglets delivered (P=0.67). For sows mated in lactation the litter performance as similar to the conventionally weaned sows.

The litter growth characteristics are shown in table 8. The treatment allocation had a marginally non-significant effect on the day 14 liveweight (P=0.06). The treatment effects on the day 23 weight were significant (P=0.003). The piglet growth rate from day 14 to 23 was strongly dependent on the separation time. The growth rate of piglets separated for the first 3 days (group 2) or from the third day until mating (group 3) was significantly lower when compared to the control conventionally weaned piglets (group 5) and those from sows treated with PG600 alone (group 1) (P<0.05). The piglets from sows separated for the extended period from PG600 treatment until mating (Groups 4 and 6) had a growth rate significantly lower the other treatments (P<0.05). The suckling litter size had no significant effect on day 14 weight (P=0.53), day 23 weight (P=0.15) or the growth rate from day 14 to 23 (P=0.16).

Group	1	2	3	4	5	6	
Treatment	**PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1-3**	**PG 600 with 'SEP' days 3 to mating**	**No PG 600 'SEP' day 1 to mating**	**No PG 600 and no 'SEP'**	**PG 600 with 'SEP' days 1 to mating**	**P Value**
Sow parity			Multi			Primi	
			Piglet growth rate days 14 to 23 of age				
Average 14-day piglet weight (kg)	5.03 ± 0.17	5.20 ± 0.19	5.31 ± 0.19	5.06 ± 0.20	4.58 ± 0.19	4.75 ± 0.17	0.06
Average 23-day piglet weight (kg)	7.05 ± 0.21^{a}	6.80 ± 0.24^{a}	6.78 ± 0.57^{a}	5.89 ± 0.24^{b}	6.46 ± 0.23^{a}	5.81 ± 0.21^{b}	0.003
Average piglet daily gain day 14-23 (g)	235 ± 47^{a}	175 ± 48^{b}	174 ± 15^{b}	99 ± 15^{c}	229 ± 15^{a}	122 ± 17^{c}	<0.001

Table 8: The growth performance of litters from sows treated to the oestrus induction protocols during lactation. Values are given as mean ± SEM. Within a row values with different superscripts are significantly different (P<0.05).

Summary

1. The reduction in treatment group size because of management issues was disappointing and limited to some extend the power of the statistical analysis.
2. Treatment with PG600 and piglet separation for 3 days was sufficient to obtain 80-85% mating in lactation. For these treatments the farrowing rate was similar to the control sows mated after weaning.
3. Overall for multiparous sows, 95% of sows were mated either in lactation or after weaning. By checking for oestrus in lactation, sows that spontaneously ovulate are being detected and mated. Around 10% of primiparous sows were not mated either in lactation or after weaning.
4. PG600 treatment alone had no effect on the percentage of sows mated in lactation. However, PG600 use may have an influence on litter size especially for sows subjected to oestrus induction where boar exposure alone is used.
5. Piglet separation alone for multiparous sows was sufficient to have 80% of sows mated in lactation although a non-significant trend for the return to oestrus rate and farrowing rate to be lower than that observed for control sows mated after weaning suggests that this needs to be further investigated.
6. Primiparous sows treated with PG600 and piglet separation had a lactation mating percentage equivalent to that of mutilparous sows. The high rate of lactation oestrus

observed in lactating primiparous sows is interesting because it is generally considered that the reproductive performance of these sows is less than older parity sows. However, a non-significant trend for the farrowing rate to be lower than that observed for control sows mated after weaning suggests that this needs to be further investigated.

7. For control sows 46% displayed oestrus during lactation. While these sows experience fenceline boar exposure there remains the possibility that at least some of these sows had a spontaneously ovulation.

3.1.3. Study 3. Duration of piglet separation.

The mating outcomes are given in table 9. Treatments for groups 1-3 were started on an average of day 17.4 ± 0.2 of lactation, but ranged from day 15 to 20 for individual sows. For group 4 sows the treatments were started on an average of day 22.4 ± 0.3 of lactation, but ranged from day 19 to 25 for individual sows. There were no differences in average parity for experimental groups (P=0.64). The suckling litter size was not different between treatments (P=0.53), with it averaging 9.7 piglets per sow. The weaning age for groups 1-3 averaged 26.4 days and this was significantly different to 28.5 days for group 4 (P<0.05).

Treatment had no significant effect on the proportion of sows mated during lactation (P=0.50). In all groups the remaining sows were mated after weaning. Treatment effects on the time from the start of induction until mating were significant (P<0.001). Separation for 3 days overnight (16h) early in lactation (day 17.5) without PG600 treatment increased the time from induction to mating compared to other treatments while the same treatment regime applied later in lactation (day 22.5) reduce the time from induction to mating (P<0.05). Differences in the weaning to mating interval were not analysed at the sow numbers in treatments were low.

Group	1	2	3	4	P value
Treatment	No PG 600 SEP* 3 day x16h (early)	PG 600 SEP* 3 day x16h (early)	PG 600 SEP* 3 day x8h (early)	PG 600 SEP* 3 day x16h (Late)	
Number of sows	27	29	28	28	-
Culled before weaning	1	1	1	1	-
Potential sows to be mated	26	28	27	27	
Average parity	4.11 ± 0.32	4.18 ± 0.31	4.57 ± 0.32	4.53 ± 0.31	0.64
Average litter size suckled in lactation	10.1± 0.3	9.7 ± 0.3	9.5 ± 0.3	9.6 ± 0.3	0.53
Days from farrowing to induction	17.4 ± 0.3^{b}	17.6 ± 0.2^{b}	17.4 ± 0.2^{b}	22.4 ± 0.3^{a}	<0.001
Weaning age	26.4 ± 0.3^{b}	26.5 ± 0.2^{b}	26.4 ± 0.2^{b}	28.5 ± 0.3^{a}	<0.001
% sows mated in lactation (number)	84.6 (22/26)	92.8 (26/28)	77.8 (21/27)	85.2 (23/27)	0.50
% mated after weaning (Number)	15.4 (4/26)	7.2 (2/28)	22.2 (6/27)	14.8 (4/27)	0.50
Total mated	100 (26/26)	100 (28/28)	100 (27/27)	100 (27/27)	-
Days mated after Induction started	5.41 ± 0.21^{a}	4.65 ± 0.20^{b}	4.48 ± 0.23^{b}	3.74 ± 0.22^{c}	<0.001
Days mated after Weaning	4.75 ± 2.8	4.00 ± 3.93	5.00 ± 2.27	13.25 ± 2.8	**

Table 9: The mating outcomes of sows following oestrus induction during lactation. Within a row values with different superscripts are significantly different ($P<0.05$).

* SEP- piglet separation

** Low number of sows in some treatments limited any analysis. The long weaning to mating interval for the group 4 sows is due to two sows which showed oestrus 21 and 24 days after weaning suggesting that they may have been in oestrus immediately after weaning and were not detected in the commercial herd, because detection did not begin until 3 days after weaning.

Group	1	2	3	4	P value
Treatment	No PG 600 'SEP' 3 day x16h (early)	PG 600 'SEP' 3 day x16h (early)	PG 600 'SEP' 3 day x8h (early)	PG 600 'SEP' 3 day x16h (late)	
Potential sows pregnant	26	28	27	27	
% mated in lactation and NIP* day 40 (%)[1] (number)	9.1 (2/22)	11.5 (3/26)	19.0 (4/21)	26.1 (6/23)	0.44
% mated after weaning and NIP* day 40 (%)[2] (number)	0 (0/4)	0 (0/2)	0 (0/6)	25.0 (1/4)	ND
% mated in lactation and NIP* after day 40 (%)[1] (number)	4.5 (1/22)	3.8 (1/26)	14.3 (3/21)	4.3 (1/23)	ND
% mated after weaning and NIP* after day 40 (%)[2] (number)	0 (0/4)	0 (0/2)	0 (0/6)	0 (0/4)	ND
% farrowed and mated in Lactation (number)[1]	86.4 (19/22)	84.6 (22/26)	66.7 (14/21)	69.6 (16/23)	0.17
% farrowed and mated after weaning (number)[2]	100.0 (4/4)	100.0 (2/2)	100.0 (6/6)	100.0 (4/4)	1.00
Total % farrowed (number)[3]	88.4 (23/26)	85.7 (24/28)	74.1 (20/27)	70.1 (19/27)	0.30

Table 10: The pregnancy outcomes of sows following oestrus induction during lactation. Within a row values with different superscripts are significantly different (P<0.05).
[1] %calculated relative to the number mated in lactation
[2] %calculated relative to the number mated after weaning
[3] %calculated relative to the total number mated
*NIP – returned to oestrus or not pregnant
ND-Analysis not conducted because of low treatment numbers

The pregnancy outcomes are given in table 10. Treatment effects on the proportion of sows returning to oestrus or not pregnant at day 40 were not different (P=0.44). Also, the treatments had no effect on the proportion of sows that were mated in lactation and went on to successfully farrow (P=0.17) or on the proportion of sows that were mated after weaning and went on to farrow (P=1.00). So the number of sows that farrowed as a proportion of the total that were mated were similar (P=0.30). While there were no statistical differences, the resulting farrowing rates might raise some concerns about the 8/h period (group) of separation as potentially being too short to achieve good farrowing results. Similarly, the induction of oestrus and mating close to the time when sows are weaned could also be a potential concern.

Treatment Group	1	2	3	4	
Treatment	No PG 600 'SEP' 3 day x16h (early)	PG 600 'SEP' 3 day x16h (early	PG 600 'SEP' 3 day x8h (early)	PG 600 'SEP' 3 day x16h L(ate)	P value
All sows that farrowed					
Born alive	10.43 ± 0.52	11.65 ± 0.57	11.74± 0.79	10.31± 0.73	0.25
Stillbirths	0.57 ± 0.21^{b}	0.83 ± 0.26^{ab}	0.60 ± 0.20^{b}	1.58 ± 0.29^{a}	0.05
Mummified	0.39 ± 0.16	0.09 ± 0.06	0.10 ± 0.07	0.31 ± 0.13	0.10
Total born	11.39 ± 0.55	12.56 ± 0.72	12.55± 0.85	12.21 ± 0.69	0.76
Sows farrowed that were mated in lactation					
Born alive	10.42 ± 0.59	11.47 ± 0.61	11.79 ± 1.03	10.50± 0.71	0.51
Stillbirths	0.47 ± 0.20^{b}	0.61 ± 0.20^{b}	0.50 ± 0.20^{b}	1.81 ± 0.46^{a}	0.004
Mummified	0.42 ± 0.19	0.05 ± 0.05	0.07 ± 0.07	0.31 ± 0.15	0.27
Total born	11.31 ± 0.63	12.14 ± 0.76	12.35± 1.08	12.63 ± 0.63	0.76
Sows farrowed that were mated after weaning					
Born alive	10.50 ± 1.00	13.50 ± 0.16	11.50 ± 0.72	8.43 ± 3.18	ND
Stillbirths	1.00 ± 0.82	3.00 ± 0.65	0.67 ± 0.49	1.36 ± 0.33	ND
Mummified	0.25 ± 0.29	0.50 ± 0.16	0.00	0.43 ± 0.33	ND
Total born	11.75 ± 0.87	17.0 ± 0.32	12.47 ± 1.11	9.98 ± 3.00	ND

Table 11: The subsequent farrowing performance for sows following oestrus induction during lactation. Values are given as mean ± SEM. Within a row values with different superscripts are significantly different ($P<0.05$).
ND-Analysis not conducted because of low treatment numbers

Farrowing performance is shown in table 11. For all sows farrowing that were mated in lactation there were no treatment ($P=0.76$), parity ($P=0.68$), the average sow lifetime performance of total born (P=0.53) and the day of lactation treatment started (P=0.92) effects on the total litter size born. Similarly, there were no treatment (P=0.51), average sow lifetime performance of total born (P=0.63), parity (P=0.48) and day of lactation treatment started (P=0.82) effects on total number born alive. The average sow lifetime performance of total born (P=0.68), parity (P=0.45) and day of lactation treatment started (P=0.20) had no effects on the stillborn number but the treatment effects were significant (P=0.004). The number stillborn was significantly higher (P<0.05) for the sows treated late in lactation (day 22.5) compared to sows treated earlier in lactation (day 17.4). There were no treatment (P=0.27), parity (P=0.61), the average sow lifetime performance of total born (P=0.51) and the day of lactation treatment started (P=0.35) effects on the total number of mummified piglets born.

Treatment Group	1	2	3	4	
Treatment	No PG 600 'SEP' 3 day x16h (early)	PG 600 'SEP' 3 day x16h (early	PG 600 'SEP' 3 day x8h (early)	PG 600 'SEP' 3 day x16h (late)	P value
Average 14-day piglet weight (kg)	5.28 ± 0.17	5.42 ± 0.17	5.09 ± 0.15	5.68 ± 0.22	0.39
Average 23-day piglet weight (kg)	6.63 ± 0.22^{b}	6.52 ± 0.20^{b}	7.39 ± 0.17^{a}	6.88 ± 0.25^{b}	<0.01
Average piglet daily gain day 14-23 (g)	176 ± 14^{b}	143 ± 10^{b}	248 ± 14^{a}	182 ± 29^{b}	<0.001

Table 12: The growth performance for the litters suckling sows treated to the oestrus induction protocols during lactation. Values are given as mean ± SEM. Within a row values with different superscripts are significantly different (P<0.05).

The piglet growth rate is given in table 12. Treatment (P=0.39) and parity (0.09) both had no significant effects on day 14 weight. Treatment (P<0.01) had a significant effect on day 23 live weight. Parity (P=0.11) and age treatment started (P=0.10) both had no significant effects on day 23 weight. Piglets from the treatment where separation was for only 8h/d had heavier day 23 weights than piglets from other treatments (P<0.05), and this was similar to the growth rate observed in previous studies for control treatments where there was no piglet separation.

Treatment (P<0.001) and the age treatment started (P=0.03) had significant effects on piglet growth rate from days 14 to 23 of age. The growth rate of piglets separated for only 8h for three days was significantly greater (P<0.05) than for the other treatments which where all similar.

Summary

1. Starting on day 17 of lactation sixteen hours of overnight separation without PG600 was sufficient to induce 85% of sows to display lactational oestrus which was not different to using PG 600 and 16 h of separation where 93% of sows responded
2. Use of PG600 with 8 h separation resulted 78% of sows displaying oestrus and this was not different to 16h of separation.
3. With 8 h of separation further evaluation using larger group sizes is needed because there was some evidence that the return to oestrus and subsequent litter size were lower than when 16h of separation is used and needs to be checked.
4. Using 16 of separation starting at day 17 resulted in 85% of the sows mated in lactation going on to farrow. It was around 70% when the induction started at day 22
5. A combination of lactation oestrus induction and mating after weaning resulted in 100% of sows being mated within 5-6 days of weaning (Groups 1-3).
6. The longer WOI for group 4 sows was the result of 2 sows having a WOI indicative of return to oestrus a full cycle after weaning, suggesting that an oestrus occurring around the time of weaning had been missed.
7. Starting the induction protocol at a time that results in mating just prior to weaning and moving the sows (group 4), could create issues associated litter size and return to oestrus and increased still birth rate.
8. Separation for 8h instead of 16h has important positive effects on piglet growth rate.
9. A period of 8 h separation at a later time in lactation, say 20, might be sufficient for oestrus induction.

3.1.4. Study 4: Occurrence of spontaneous ovulation and oestrus induction in commercial lactating sows, using boar exposure alone or after gonadotropin treatment at farrowing.

Group A – Untreated control sows

Ovaries were collected from 59 sows from farrowing 1 (weaned day 29) and 60 sows from farrowing 4 (weaned day 25). Of these 119 sows, 10 from farrowing 1 and 7 from farrowing 2 had functional CL at the time of collection. From these observations, 15.1% of the sows had spontaneously ovulated during the period of lactation. The litter size weaned varied from 4 to 13 with 89% of sows weaning 7-11 piglets. The percentage of sows with functional CL with different weaning litter sizes is given in table 13.

For those sows without functional CL the number of large follicles on the ovaries was 21.6±0.4 and number of small follicles was 13.0 ±1.0. Parity (P=0.71), lactation length (P=0.87) or litter size weaned (P=0.35) had no effects on the large follicle number observed on the ovaries. Similarly, parity (P=0.19), lactation length (P=0.36) or litter size weaned (P=0.28) had no effects on the small follicle number observed on the ovaries.

Sow Numbers	Litter size weaned	Number with functional CL
2	4	1 (50.0%)
2	5	1 (50.0%)
7	6	0 (0%)
17	7	3 (17.6%)
26	8	4 (15.4%)
35	9	5 (14.3%)
18	10	2 (11.1%)
10	11	0 (0%)
1	12	0 (0%)
1	13	0 (0%)

Table 13: The presence of functional CL on the ovaries of group A sows with different weaning litter sizes.

Groups B and C – Boar exposure +/- gondotrophin treatment at farrowing.

Boar exposure commenced on day 14.7±0.2 of lactation for group C sows and on day 14.8±0.2 of lactation for group B sows, with this being 11.7±0.2 days after the hCG injection was given.

The percentage of sows displaying standing oestrus behavior is given in table 14. The farrowing week had no significant effect on the number of sows displaying standing oestrus (P=0.85). When replicates were combined the number of sows displaying oestrus, treatment sows B (21.5%) and treatment C sows (24.6%) was not different (P=0.71). Farrowing week had no effect on the number of sows having functional CL at the time of slaughter (P=0.45). More Group B sows had CL's at slaughter (P=0.03).

Treatment	Replicate	Number	Number displaying	% displaying	Number	%

		of sows	oestrus	oestrus	with CL's	with CL's
B PMSG/hCG + boar exposure	Farrowing week 2	34	8	23.5	14	41.1
	Farrowing week 3	31	6	19.3	13	41.9
	Total	65	14	21.5	27	41.5
C Boar exposure alone	Farrowing week 2	33	7	21.2	8	24.2
	Farrowing week 3	27	8	29.6	6	22.2
	Total	60	15	25.0	14	23.3

Table 14: The percentage of sows displaying standing oestrus for both replicates of treatments B and C.

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Sows from group C were bled on day 11.8±0.2 of lactation and those of group B on day 11.7±0.2 of lactation which was 8.7±0.2 days after the hCG injection. The plasma progesterone concentrations for group C and B sows are given in figures 3 and 4, respectively. Only one of the 58 group C sows had a progesterone concentration >2 ng/mL. Thirteen of the 61 group B sows bled had a plasma progesterone concentration >2 ng/mL. The difference between the groups was significant (P=0.04).

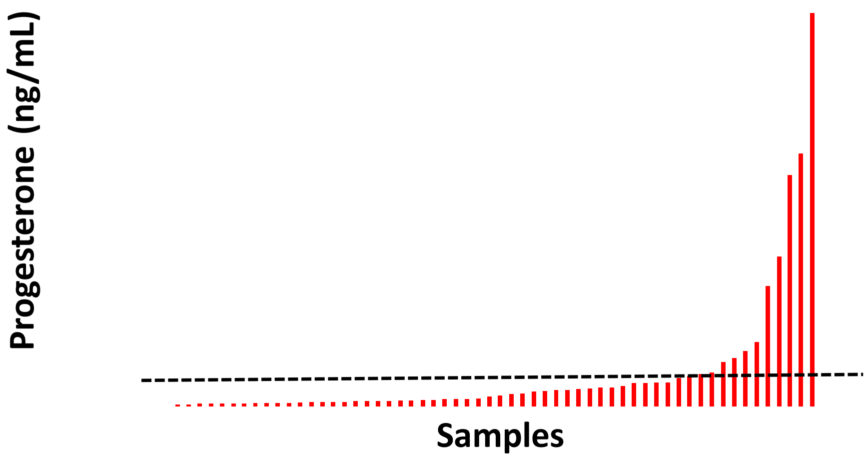

Figure 3 - Group B. The plasma progesterone concentrations for sows treated with gonoadotrophins at farrowing.

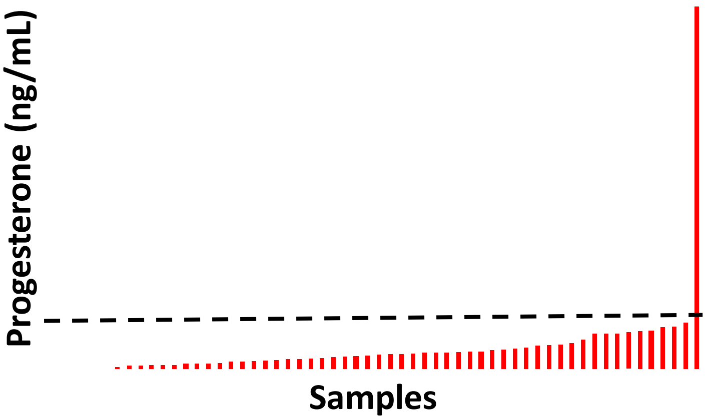

Figure 4 - Group C. The plasma progesterone concentrations for sows untreated at farrowing.

For treatment group B sows, there were 27 that had functional CL on the day of collection. Of the 14 sows displaying standing oestrus only 10 had functional CL's at slaughter with only one of these having a progesterone concentration of >2 ng/mL at the time of the blood sampling. There were 4 sows identified as having a standing oestrus during lactation but having no CL's present on the ovary at slaughter. Seventeen sows had CL's at slaughter but showed no evidence of oestrus during lactation. Ten of these had progesterone concentrations >2ng/mL and could represent sows where gonadotrophin induced ovulations at farrowing had persisted through to slaughter. What fate the remaining 7 sows with CL's at slaughter and low progesterone concentration (<2 ng/mL) at the blood sampling had, is unclear and identifies the limitations imposed by the minimal blood sampling regime. It supports the need for real time ultrasound analysis of follicle development to clearly delinate what happens during lactation to follicle development.

For treatment group C sows, of the 15 sows displaying standing oestrus only 11 had CL's at slaughter with only one of these 15 having a progesterone concentration of >2 ng/mL at the time of the blood sampling. There were 4 sows identified as having a standing oestrus during lactation but having no CL's present on the ovary at slaughter.

Collectively, of the 29 sows showing standing oestrus there were 8 which failed to have CL's at slaughter suggesting that they had displayed oestrus but had not ovulated.

The suckling litter size (see table 15) had no significant effects on the number of sows displaying standing oestrus or those displaying oestrus and having CL's present at slaughter.

Litter size suckled	Sow number	Displaying standing oestrus	Displaying standing oestrus with CL's
5-7	21	7	6
8-9	54	11	8
10-13	50	11	7
P value		0.50	0.44

Table 15: The number for sows with different suckling litter sizes and displaying standing oestrus and functional CL's at slaughter.

Summary

1. Our earlier assertions that spontaneous ovulation was occurring is supported by the observations made here. The current study where the weaning age was 25-29 days, the rate of spontaneous ovulation was around 15%.

2. The rate of spontaneous ovulation would increase as weaning age increased. This would seem to be a significant issue requiring consideration in any lactational oestrus induction protocol but also when conventional weaning is used as it would result in long weaning to oestrus interval.

3. When fenceline boar exposure is used alone (group C), 21-25% of sows displayed oestrus. If it is assumed that some of these sows spontaneously ovulated and so the effect of the boar exposure would be limited. From the results it could be speculated that 15% of sows had spontaneously ovulated. This leaves around 10% responding to the boar and 15-20% responding to the gonadotrophin treatment at farrowing. Such extrapolations need to be made with a high degree of caution.

4. Interestingly, of sows displaying standing oestrus (groups B and C combined) and having limited boar exposure, 27.6% failed to ovulate as they had no functional CLs at slaughter. One consideration is that fenceline boar exposure may help induce sows to display oestrus but not ovulation. The use of boar exposure alone might require the use of some degree of gonadotrophic support to ensure ovulation.

5. It was proposed that by using gonadotrophins at farrowing sows could be induced to ovulate and form functional CL which would act to initiate a return to oestrus later in lactation in a synchronised manner and prevent sows from spontaneously ovulating. The low number of sows having progesterone concentrations >2ng/mL would indicated that the gonadotrophin treatment at farrowing failed to induce ovulation in many sows.

6. There were 17 sows in group B that had functional CL at slaughter but did not displaying a standing oestrus. Only 10 of these had plasma progesterone concentrations >2 ng/mL which suggested that they had responded to the gonadotrophin treatment at farrowing. It's probable that for these 10 sows the CL observed at slaughter had persisted from farrowing.

7. To better understand oestrus induction in lactation there is a need for much better evaluation of ovarian follicle development.

4. Application of Research

The Australian pig industry is committed to welfare-optimal, efficient pork production systems. Central to this are changes in reproductive management that eliminates the need for gestation sow stalls. A further goal is to improve the quality and survivability of piglets without compromising production efficiency.

The overall objective of the current project was to refine mating in lactation strategies that support confinement free gestational sow housing and allow increased weaning age without diminishing production efficiency.

The research has identified:

1. For the genotype used in the current study there are a percentage of sows that spontaneously ovulate during lactation. This is most probably occurring in all modern genotypes. The percentage of sows spontaneously ovulation in a herd will depend on the weaning age. As the age increases it is speculated that the percentage will also increase.

This has some important management implications:

a. Sows having a spontaneous lactational ovulation will have a long weaning to oestrus interval and under past reproductive dogma could result in sows prematurely being culled for poor reproductive performance.

b. Failure to check for oestrus immediately after weaning could result in some sows being missed or others mated towards the end of the oestrus period, resulting in poorer farrowing performance.

c. Would limit mating rate under normal mating practices to around 85% for the genotype used here when weaning at 26-28 days.

d. Needs to be considered as an obstacle to cope with in any lactational oestrus induction protocol

2. Oestrus induction protocols can be initiated as early as day 14 of lactation but based on reservations we have as to the effect on litter size and farrowing rate, in commercial practice it would be best to limit any induction protocol to day 16 of lactation.

3. The starting induction protocol of using PG600 injection, with piglet separation until mating with fenceline boar exposure has been refined

4. The PG600 alone has no effect and is not needed when piglet separation is included.

5. The piglet separation period can be limited to overnight (16h) for 3 days starting immediately after the injection or on the 3rd day after the injection until mating. This has a positive effect on growth rate on the piglets compared to the longer separation period used in the initial protocol.

6. Staring on day 17 of lactation, it is proposed that separation for 8h for 3 days while giving good mating results in lactation could have unwanted effects on return to oestrus

rate and subsequent litter size. A significant value of this separation regime is that it had little negative effect on piglet growth rate. Implementing this separation regime later in lactation could be successful and needs to be tested.

7. Using PG600 and piglet separation in primiprous sows resulted in similar lactational mating rates as for multiparous sows. However, there could be negative effects on return to oestrus rate and litter size and there is a need for more research in this parity group.

8. Fenceline boar exposure alone is not sufficient to induce lactational oestrus in a high percentage of sows.

9. It is proposed that any degree of boar exposure could result in a percentage of sows displaying oestrus but failing to ovulate. There may be the need to consider the used of gaonadotrophic support if boar exposure alone to be used without piglet separation.

The financial benefit to the industry really relates to the benefits resulting from a sustainable pork industry. The use of gestation stalls for sows has been considered the major welfare concern for consumers. The Australian pork industry relies financially on the sale of fresh pork. One major supermarket chain has committed to only accepting fresh pork supplied from entirely stall-free systems in 2014 onwards. The industry needs to find viable production systems in the absence of gestation stalls. Mating in lactation uncouples mating from weaning and supports the development of other management options in confinement free gestation and farrowing housing systems. It will also allow for increased weaning age and gradual weaning which could provide solutions to 'weaner setback' and limit the need for antibiotic used in weaner pigs.

With the approach taken here to oestrus induction, piglet separation for a period appears to be the essential aspect of the protocol. This is a limitation to its commercial implementation using current farrowing (crates) systems. If separation of piglets remains a critical requirement for any induction protocol it might be more easily implemented in confinement free farrowing systems with gradual weaning protocols.

This research continues to develop the knowledge need by the industry to develop new sow management systems that allow for reduced confinement during production in line with consumer and retailer demands.

5. Conclusion

Present and long held dogma on the need to have sows weaned before they will come in to oestrus and ovulate needs to be discarded. Modern genotypes have been directly or indirectly been selected for short weaning to oestrus intervals and this could have resulted in sows being less inhibited by the suckling stimulus allowing ovulation during lactation. As a consequence some sows will spontaneously ovulate during lactation and reproductive management needs to take this in to consideration.

Using at least piglet separation and minimal boar exposure, a high percentage of sows can be induced to display oestrus and be mated in lactation. The mating results in good farrowing rates and litter size if the induction starts after day 16 of lactation. The need to separate piglets from the sow remains an obstacle to easy commercial implementation.

6. Limitations/Risks

The risks of the lactational oestrus induction are minimal. If the separation of piglets and the sow is required, there are some issues associated with piglet growth and wellbeing but further research could modify the induction protocol where this is of no concern.

7. Recommendations

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

1. Further research funding to continue the refinement of the induction protocol. Aspects that need consideration are the piglet and sows separation time and how to manage those sows having spontaneous ovulation and the likely small percentage of sows that might not respond to the procedure.
2. Identify how an induction protocol can be implemented in new sow housing systems that reduce confinement in gestation and lactation.
3. Further evaluate the role that increased boar exposure has on lactational oestrus induction.
4. Support research that investigates the role that sow metabolic state and suckling litter size have on the response to lactational oestrus induction.
5. Determine the effect of genotype on lactational oestrus induction.
6. Have funding bodies provide sufficient resources to support experimental group sizes, large enough to adequately determine statistical significance.

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