Assessing behavioural and physiological implications of intermittent suckling on primiparous sows and their litters

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Abstract. The objective of the current study was to determine the implications of intermittent suckling (IS) on primiparous sows and there litters. Behavioural observations, udder scores, return to nursing and salivary cortisol concentrations were measured. An intermittent suckling protocol was applied to 22 primiparous sows and their litters. At three weeks of age piglets were separated for eight hours a day, for seven days prior to weaning. Control litters had the sow continuously present until weaning. Video data was collected; one hour before and after separation and one hour before and after rejoining on days one, three and six. Coritsol samples were collected at 06:00 h on day one and then at 12:00 h on day two, four and seven. Udder scoring was carried out at the start of separation, day two of separation and at weaning. Return to suckling bouts were recorded on days one, three and six for two hours after rejoining. The study found that during periods of separation the IS piglets spent significantly more time resting in comparison to control litters (postsep 86.9±1.6% vs 76.5±2.3%; prejoin 79.1±2.0% vs 64.2±2.2%; $P<0.05$). Once rejoined to the sow, piglets activity significantly increased ($P<0.05$), but then gradually declined over the one hour postjoin period. On day two, postsep cortisol concentrations for IS piglets were significantly greater than base levels seen pre-separation on day one ($P<0.05$). However, day four and seven cortisol concentrations were similar to the base concentration, suggesting that piglets had adapted to the separation. Greater activity around the udder during the rejoining period, determined by increased time spend massaging the udder and nursing ($P<0.05$) and a greater numbers of suckling bouts in IS litters ($P<0.05$), did not lead to increased physical damage of the udder. Sow behavior was altered during the rejoining period, with IS sows spending more time standing (26.2±2.8% vs 8.5±2.2%;

P<0.05). However, cortisol concentrations for sows were not significantly different between control and IS treatments (P=0.34). Therefore, based on the minimal changes in behavior and cortisol concentrations of piglets and sows during separation, eight hours separation over seven days does not appear to adversely affect piglet or sow welfare.

Key words: weaning, separation, cortisol, udder score

Introduction

Traditionally within the Australian pig industry, piglets are weaned from sows at three to four weeks of age (Langendijk *et al*. 2007a,b). This may raise welfare concerns for the piglets, as the abrupt change to a solid weaning diet and mixing of unfamiliar litters leads to stress and reduced growth (Kuller *et al*. 2004). When lactation length is shortened to between four and 21 days post farrowing, reduced reproductive performance is observed (Cole *et al*. 1975; Varley and Cole 1978; Gaustad-Aas *et al*. 2004), with lower ovulation rates, lower conception rates, smaller litter sizes at the subsequent farrowing, and a greater chance of the sow developing cystic ovaries (Peters *et al*. 1969; Cole *et al*. 1975). In spite of this, a reduction in lactation length results in faster reproductive turnaround and therefore more litters per sow each year, which in turn supports increased profitability (Petchey and Jolly 1979). While early weaning has obvious economic benefits, an increased lactation length assists in the growth and development of the piglets, yet this will come at a cost to sow lifetime reproductive performance (Berkeveld *et al*. 2007a,b; Hoshino and Koketsu 2008). The need for economically viable production which promotes both sow fertility and piglet growth has led to considerable research into methods to reduce the farrowing to oestrus interval or non-productive days of the sow without negatively impacting upon the welfare of sows or piglets (Kirkwood and Thacker 1989; Zak *et al*. 2008). Currently, the most successful strategy has been to induce oestrus during lactation, which also allows for an increased weaning age, improving the welfare of piglets at weaning (Langendijk *et al*. 2007a; Gerritsen *et al*. 2008).

Suckling inhibition is a major factor suppressing ovarian follicle development in lactating sows and needs to be limited if sows are to display oestrus and ovulate during lactation (Newtown *et al*. 1987). Intermittent suckling has been identified as a method to alleviate the restraints placed on ovulation due to the suckling suppression (Kuller *et al*. 2004). This process involves separating the sow and piglets for a period of time each day after day 14 of lactation. However, a difference in the response to separation has been identified between primiparous and multiparous sows (Hulten *et al*. 2006). During lactation, primiparous sows have been recognised as forming stronger bonds with their litters (Hulten *et al*. 2006). Without separation, primiparous sows are more likely to remain anoestrous during lactation, while multiparous sows are more likely to spontaneously ovulate (Kunavongkrit *et al*. 1982; Newtown *et al*. 1987). While separating sows and their piglets prior to weaning can stimulate sows into a lactational oestrus, the consequences of this separation on the welfare of both the sow and piglets have yet to be explored.

The welfare of an animal is its state in regards to its attempts to cope with its environment. When animals are faced with conditions in which they cannot cope, their individual fitness may be reduced as a consequence of physiological and behavioural responses. Attempts to cope include the functioning of the body repair system, physiological stress responses, immunological defenses and behavioural changes (Broom 1986).

Using the definition of Broom (1986), welfare risks can be studied at two levels: the behavioural and physiological responses of the animal to the challenge, and secondly the consequent biological cost to the animal (i.e. reduced biological

fitness such as reduced growth rate). The behavioural and physiological changes by the animal to the environment are the response that the animal uses in an attempt to re-establish homeostasis. Substantial and prolonged behavioural and physiological responses can have effects on biological fitness by affecting growth performance, reproduction, injury, health and survival (Broom and Jonson 1993; Barnett and Hemsworth, 2010).

Therefore, the overall objective of this experiment was to identify the implications of subjecting primiparous sows and their litters to an intermittent suckling regime and to assess the behaviour and physiological stress responses of the sow and her piglets. The hypothesis was that separation would not cause alterations in the behaviour or physiology of the sows and piglets that indicated the animals were distressed.

Materials and Method

All animal procedures were conducted with prior institutional ethical approval under the requirements of the NSW Prevention of Cruelty to Animals Act 1985, in accordance with the National Health and Medical Research Council/Commonwealth Scientific and Industrial Research Organisation/Australian Animal Commission *Code of Practice for the Care and Use of Animals for Scientific Purposes.*

Animals and accommodation

Research was conducted at the Research and Innovation unit of Rivalea Australia, a large commercial piggery in Corowa NSW, during June and July of

2013. The study described in this paper was associated with a larger study, which focused on the sow's return to oestrus during lactation. A total of 22 Large White x Landrace primiparous sows and their litters were used for the experiment over three consecutive weekly batch farrowings. Each shed (farrowing unit) was comprised of 64 farrowing crates (1.67 wide x 2.25 m long). Crates had slatted floors with rubber mats beneath a single overhanging heat lamp provided for the piglets (Diagram 1). Sows were fed three times a day (*ad libitum*) and had unlimited access to water. Piglets could move freely around the farrowing crate and had unlimited access to drinking water. In addition, they had access to creep feed *ad libitum* from the start of the separation period. All piglets were tail docked at day one of age and no teeth clipping was performed. Males were left intact. Gilts were randomly assigned pens based on the order they entered the farrowing shed. Treatment and control groups were housed on opposing sides of the shed to minimize the effects of boar exposure, which was part of the larger study; on control sows. The piglets were weaned at approximately 28 days of age.

Treatments

The two treatments were:

Control group (C) – A conventional lactation in which litters remained with the sow throughout until weaning.

Intermittent suckled groups (IS) – Seven days prior to weaning (denoted as day one), piglets were separated from the sow for eight hours each day (from 07:00 to 15:00 h). A board was positioned between the sow and her litter within the crate. Separated piglets were then given access to both water and creep feed

during separation (Diagram 2). Approximately 30 minutes prior to rejoining the IS piglets were provided with *ad libitum* supplemental milk as an attempt to reduce the suckling intensity when they rejoined the sow.

Behavioural observations

Digital video cameras (Signet; Model OV-3063) and recorders (Electrus Distribution, Rydalmere, NSW, Australia) were set up above each farrowing crate. Video surveillance of sows and piglets in individual crates was conducted from 06:00 until 18:00 h on days one, three and six after the start of separation. Four piglets per litter were selected as focal animals for cortisol sampling and behavioural observations. Each sow and four piglets within the litter had their posture and activities recorded in the following time frames; one hour before separation (06:00 to 07:00 h) 'presep'; and one hour after separation (09:00 to 10:00 h) 'postsep'; then one hour before rejoining (13:00 to 14:00 h) 'prejoin'; and one hour after rejoining (15:00 to 16:00 h) 'postjoin'. The piglets assigned to cortisol sampling were also those used for behavioural observations; with a single observer analysing all video data. For each hour of observation, the sow's and piglets' behaviour was recorded continuously for one minute every five minutes (12 minutes in total; Diagram 3). The postures and activities recorded for each sow and piglets are described in tables 1 and 2. In each pen, the light from the heat lamp obstructed the view of piglets, therefore while piglets were under the heat lamp they were classified as resting.

There were periods where equipment failure limited the number of successful recordings in each time frame. The rate of successful recordings were presep 85%, postsep 78%, prejoin 83%, postjoin 90%. On day one, for replication one, a

192 power outage occurred at 12 noon restricting the number of postsep recordings
193 and gave the greatest proportion of failures.
194
195 ***Saliva sampling***
196 Saliva samples were collected on day one before separation (06:00 h), and then
197 at 12:00 to 12:30 h on days two, four and seven after separation started. Saliva
198 samples were taken in each replicate and were performed on each sow and the
199 four focal piglets in each litter. In order to obtain the greatest volume of saliva,
200 the two largest females and two largest males were selected within each litter.
201 Males were labeled A and B and females were labeled C and D. Saliva was
202 collected using a saliva collection tube (Salivettes, Sarstedt Australia, South
203 Australia, Australia) for centrifugation. Two people collected samples in order of
204 pen number (Rodate *et al*. 2010). For sows, 500mm cable ties were used to hold
205 the cotton swab, which was then placed in the sow's mouth. Sows were given one
206 minute to chew on the cotton swab. Piglets had 200mm cable ties attached to
207 one end of the cotton swab, which was coated in icing sugar. Piglets were placed
208 on each handler's lap and the cotton swab was inserted into their mouth for two
209 minutes (Escribano *et al*. 2012). Piglet sampling occurred subsequently to sow
210 sampling in order to minimize sow stress and collection occurred in two rounds.
211 The first samples were collected from piglets A and C and the second samples
212 were collected from piglets B and D. After centrifugation (3000 RPM for 6
213 minutes at 4^0C), cotton swabs were removed and saliva was stored at -20˚C until
214 required. Cortisol was then analysed using the Caymens cortisol EIA kit (No.
215 500360, Cayman Chemical Company, MI, USA). Sufficient saliva was obtained
216 from all sows and 85% of the piglets.

217

218 ***Udder scoring***

219 Udder scoring of both control and treatment sows was carried out at the start of
220 piglet separation, on day two of separation and at the time of weaning. The same
221 observer was used at all times. Udder scoring consisted of counting the number
222 of functional teats and identifying wounds. There were five possible wound
223 categories which included A, fresh scratch or cut; B, old scratch or cut; C,
224 bruising/swelling; D, damaged teat (still functional); and E, damaged teat (non
225 functional; severely damaged).

226

227 ***Suckling bouts after joining***

228 During the two hour period after rejoining, the number of lactational suckling
229 bouts was recorded. Suckling bouts were only recorded when the sow was lying
230 and presented her udder to the piglets. No record was made of suckling bouts
231 while the sow was standing due to the difficultly of determining if piglets were
232 nursing or not. Data was collected on day one, three and six of the study.

233

234 ***Statistical analysis***

235 ***Behavioural analysis*.** Data was collected from 22 sows and four piglets
236 within each litter. Statistical analysis was carried out using a Generalised Linear
237 Mixed Model (GLMM) in Genstat 15th Edition (2012). For all behaviour models
238 the random terms were, repetition, repetition x pen. The fixed terms in the final
239 model were treatment, time frame (presep, postsep, prejoin, postjoin), treatment
240 x time frame, time frame x minute, treatment x time frame x minute. For day data
241 the fix term was treatment x day and the random model was, repetition,

repetition x pen. Terms found to be non significant were dropped from the model (Table 3 and 4).

Standard significance levels were used with a P value <0.05 indicating a significant effect. Because it was considered that there would be a significant correlation between time points, whereby one time point affected the result observed at the next time point, a covariant was created for each parameter and included in the model to account for this effect. All results from the GLMM behavioural analysis are given as a probability of the sow or piglet engaging in the behaviour or not (binomial). Where effects were found to be significant, individual comparisons were made using Fisher's LSD (calculated to be 2 X SED).

Suckling bouts after rejoining analysis. Data from the 22 sows was analysed using a Linear Mixed Model in Genstat 15th Edition. For this model, the random terms were shed and pen and the fixed model was treatment plus day. Terms found to be non significant were dropped from the model and standard significant levels were used, where a P value <0.05 indicated a significant effect.

Udder score analysis. An ordinal regression using weighted values was used to analyse the udder score data and was conducted in Minitab version 16 (2013). Ordinal regression was used, as scores were categorized A-E in terms of severity. Counts on the number of wounds were used as the weighted values.

Cortisol analysis. Cortisol data was analysed using a Linear mixed model in Genstat 15th Edition (2012). For this model, the random terms were replication and pen and the fixed model terms were the treatment and day.

Results

Video observations of sow and piglet behaviour

Sow behaviour

The proportions of time spent displaying each posture and behavior for sows is given in table 3.

Posture. The total proportion of time spent lying and standing was similar between the control and IS sows in all time frames with the exception of the postjoin period. During this time the control sows spent significantly less time standing in comparison to IS sows ($P<0.05$; 8.5±2.2% vs 26.3±2.8%; see Figure 1). As such, control sows spent a significantly greater proportion of time lying during this time frame ($P<0.05$; 91.3± 2.4% vs 76.0±3.1%).

Behaviour. Behaviour of the IS sows was similar to control sows during the hour before separation. Once separation began, changes between the treatments were seen, with IS sows spending a significantly greater proportion of their time eating and drinking than did control sows during the prejoin period ($P<0.05$; 24.7±3.3 vs 19.2±3.3%). This difference continued through into the postjoin period, with IS sows spending significantly more time eating and drinking ($P <0.05$; 24.1±3.2% vs 11.9±2.7%). In addition to the significant increase in feeding activity of IS sows, behaviours including watching and playing with piglets ($P<0.05$; 31.0±2.6% vs 11.0±2.9%) and nursing (17.4±2.0%

vs 11.5±2.0%) similarly increased significantly post join. As expected, because of this increased activity, the time spent resting postjoin was significantly lower in IS sows ($P<0.05$; 42.7±3.6% vs 67.7±3.9%; Figure 2).

Piglet behaviour

The proportions of time spent displaying each posture and behavior for piglets is given in table 4.

Posture. Piglet posture remained similar between control and IS litters before separation. Once separated, there were differences in posture between the treatments. Postsep, IS piglets stood significantly ($P<0.05$) less time then control piglets (13.7±1.2% vs 26.5±1.8%). In addition IS piglets stood significantly less often during postsep in comparison to other time frames (presep 29.1±1.8%; prejoin 25.8±1.6%; postjoin 57.5±1.6%). The IS piglets spent similar proportions of time standing in the presep and prejoin periods (29.1±1.8% vs 25.8±1.6%), but both differed significantly ($P<0.05$), to the postsep (13.7±1.2%) and postjoin (57.5±1.6%) periods. This reduction in standing frequency led to a significantly greater proportion of time lying in IS litters during periods of separation (postsep 86.1±2.0%; prejoin 78.0±2.7%; Figure 3). Lying without sow contact dropped significantly once IS piglets rejoined the sows in comparison to control litters (30.3±3.4% vs 60.5±3.5%) Within this time frame IS piglets then stood significantly more than control litters ($P<0.05$; 57.5±1.6% vs 19.2±1.6%). Separated litters showed a gradual decline in the proportion of time spent standing postjoin, but this never reached a similar base level seen in control litters (Figure 4).

315 ***Behaviour***. During the experiment no aggressive behavior was observed
316 and casual observation of piglets showed no signs of injuries which may have
317 indicated aggressive behaviours. All behaviours were similar between IS and
318 control piglets prior to separation (P>0.05). During the postsep period
319 differences between treatments were observed. The IS piglets spent significantly
320 more time inactive, with increased time spent resting compared to controls
321 (P<0.05; 86.9±1.6% vs 76.5±2.3%). This increase in resting led to a significant
322 (P<0.05) decline in the proportion of time IS piglets spent walking and running
323 (2.0±0.4% vs 3.9±0.7%), being idle (6.3±0.8% vs 9.9±1.2%) and playing
324 (2.3±0.6% vs 5.4±1.2%). The proportion of time spent resting and inactive
325 continued into the prejoining time frame. Once piglets were rejoined with the
326 sow, activity levels increased. The IS piglets spent significantly less time resting
327 postjoining in comparison to control litters (P<0.05; 36.1±2.3% vs 74.2±2.6%).
328 Postjoin there was increased activity at the udder, with IS piglets massaging the
329 udder significantly more often than control (P<0.05; 50.8±2.1% vs 25.0±2.6%).
330 In addition, a significantly greater proportion of time was spent playing (P<0.05;
331 11.7±1.2% vs 1.7±1.2%), walking and running (P<0.05; 12.5±0.7% vs 3.5±0.8%),
332 idle (P<0.05; 22.4±1.0% vs 6.8±1.2%) and nudging (P<0.05; 8.6±0.4% vs
333 1.2±0.4%). Each of these behaviours peaked at the start of rejoining but
334 gradually declined over the one hour time frame (see Figures 5). Over all time
335 frames with the exception of presep, eating and drinking was significantly higher
336 (P<0.05) in IS litters compared to control litters (postsep 6.6±1.0% vs 3.2±0.7%;
337 prejoin 10.8±1.3% vs 3.6±0.7%; postjoin 8.4±0.5% vs 1.4±0.6%).
338
339

340 ***Changes across days***

341 Changes to sow behaviours and postures were examined across days one, three
342 and six. In sows no significant effect of treatment and day was found for standing
343 (P=0.63), sitting (P=0.39), lying (P=0.80), resting (P=0.07), eating and drinking
344 (P=0.08), watching piglets play (P=0.74), and rubbing (P=0.86). The time sows
345 spent watching piglets was marginally non-significant (P=0.051), with control
346 sows on day two spending proportionally more time watching piglets than on
347 other days.

348

349 For IS sows the time spent nursing was similar on days one and three but higher
350 on day six (P<0.05; d1 15.4±3.0%; d3 14.6±3.2%; d6 24.4±3.8%). For control
351 sows nursing time was higher on day three than other days (P<0.05; d1
352 10.1±3.3%; d3 17.6±4.1%; d6 9.0±3.1%).

353

354 Some changes in piglet behaviours and postures were seen across the days. The
355 proportion of time spent sitting (P=0.15), being idle (P=0.07), walking and
356 running (P=0.17), playing (P=0.34), nudging (P=0.59) and watching piglets
357 (P=0.93) were not different across days. The proportion of time spent lying with
358 (d1 20.5±7.4%; d6 8.1±3.4%) and without (d1 70.9±3.1%; d6 60.3±3.5%) sow
359 contact declined significantly (P<0.05) over the course of the experiment for IS
360 piglets, while time lying without sow contact for control litters remained similar
361 across days (P>0.05; d1 64.5±3.5%; d3 65.1±3.0%; d6 63.4±3.5%). This
362 correlated with a significant reduction in IS piglets proportion of time spent
363 resting over the course of the trial (P<0.05; d1 74.4±2.1%; d6 62.3±2.4%).

364

Significant variations across days were found for standing, eating and drinking and the time spent massaging the udder. A significant reduction in standing was seen on day three for IS litters compared to other days ($P<0.05$; d1 31.2±1.5%; d3 23.8±1.3%; d6 33.7±1.5%). The proportion of time spent eating and drinking was significantly different between day one and day three while day six was similar to both days for IS litters ($P<0.05$; d1 7.4±1.0%; d3 4.8±0.7; d3 6.4±0.9), while control litters had a significant increase in time spent eating and drinking on day six compared to other days ($P<0.05$; d1 1.7±0.4%; d3 1.5±0.4%; d6 4.1±0.7%). Overall, across all days the proportion of time spent eating and drinking was always significantly greater in IS litters compared to control ($P<0.05$). The time spent massaging the udder did not vary across days for IS piglets (d1 55.1±5.5%; d3 48.5±5.6%; d6 59.4±5.4%), while control litters had a significant increase on days three and six compared to day one ($P<0.05$; d1 19.5±4.0%; d3 32.7±5.2%; d6 28.7±4.9%).

Salivary cortisol

Piglet sex had no effect on cortisol concentrations ($P=0.633$). There was no treatment x day interaction for sow cortisol concentrations ($P=0.340$). Treatment for piglets had a significant effect on cortisol concentrations but this changed with time as the interaction between treatment and time was significant ($P=0.009$; Figure 6). The IS piglets showed a gradual decline in the concentration of cortisol during periods of separation (Figure 6). On day two of IS treatment, piglets' cortisol concentration was significantly greater than the concentration on day one, which was taken prior to separation ($P<0.05$). Samples on day four and seven showed a gradual decline from day two concentrations and were not

significantly different from the base concentrations taken on one day presep (P>005). Control piglets were similar to IS piglets in all time frames except day seven where control piglets had a significantly greater salivary cortisol concentration (P<0.05).

Udder score

No significance difference in udder injury was found between treatment and control sows (P=0.909). In addition no significant differences were found between treatments in each of the sampling time frames; Start of separation (P=0.212), separation day 2 (P=0.767) and weaning (P=0.524).

Suckling behaviour post joining

The IS sows had more suckling bouts during the rejoining period (P<0.01). Day had no effect on the number of suckling bouts post joining (P=0.771).

Discussion

The key aim of this study was to determine the behavioural and physiological implications of IS on primiparous sows and their litters. This is the first comprehensive investigation of the welfare effects of IS on primiparous sows and their litters. Based on the minimal changes in behaviour and cortisol concentrations of piglets and sows, eight hours separation over seven days does not appear to adversely impact piglet or sow welfare, as per the original hypothesis.

The results of this study indicate changes between the behaviours of IS sows and piglets compared to control sows and piglets. Piglets subjected to IS had a decreased level of activity during periods of separation, seen as an increase in resting behaviour. High periods of inactivity have been associated with symptoms of stress (Colson *et al*. 2006). In the current study, the higher level of inactivity was most likely due to a decrease in behaviours such as nursing and may be seen as an indicator of piglets' comfort in their environment, rather than a sign of distress (Berkeveld *et al*. 2007a). This interpretation is based on the salivary cortisol concentrations, which were similar between IS and control piglets during the course of the experiment.

In this study, cortisol measurements were taken as physiological indictors of stress. Obtaining saliva has been shown to be a noninvasive procedure for collecting samples for coritsol analysis (Gallagher *et al*. 2002; Escribano *et al*. 2012). In addition, when working with neonates, saliva is the most accessible body fluid (Gallagher *et al*. 2002), and has been shown to have a good correlation to blood cortisol concentrations (Escribano *et al*. 2012). For the IS treated piglets, cortisol concentration on day two, was significantly higher than the base cortisol concentrations measured prior to separation on day one. This increased cortisol concentration is most likely an acute response to separation, which was also found by Kluivers-Poodt *et al.* (2010). Similar to the current study, these researchers found that after day two of separation there were no significant effects on cortisol concentrations. The present study showed that by day four cortisol concentrations in IS piglets were similar to the base values, and this may suggest piglets had adapted to the separation procedure. While cortisol was

439 higher on day two compared to its base concentration it was not significantly
440 different to the concentrations seen in control piglets. In fact the IS and control
441 piglets had similar cortisol concentrations across all days, except day seven
442 where cortisol was significantly higher in the control piglets. The day seven
443 effects could be due to husbandry procedures, as it was noted in retrospect that
444 piglets in the experiment had been vaccinated roughly 30 minutes before saliva
445 samples were taken on day seven. The lower response to handling, determined
446 by a lower cortisol concentration, in IS piglets could be due to piglets being more
447 habituated to handling during the experiment (Rodarte 2010). The handling
448 during separation could have also reduced the fear response to human handling
449 during the vaccination procedure (Day *et al*. 2002).
450
451 Once IS piglets were rejoined with the sow, increased levels of activity were
452 observed. Berkeveld *et al.* (2007b) also demonstrated increased activity after
453 rejoining piglets and sows following 12 hours of separation. There was anecdotal
454 evidence that the greater proportion of time spent at the udder and nudging the
455 sow in the IS treatment may cause discomfort to the sow and result in udder
456 injury. While there was a greater level of activity around the sows once piglets
457 were rejoined, activity gradually declined within the one hour period after
458 rejoining. However, the activity level did not decline to the same level as the
459 control piglets during this same time frame (Figure 5). Heightened activity of the
460 piglets post joining, with a greater proportion of time spent playing, which is a
461 positive welfare indicator, could support the view that the piglets were in a
462 positive emotional state once rejoined with the sow (Nunes 2004; Cameron
463 2008).

Sow activity remained similar between IS and control treatments with the intermittent suckling procedure leading to no significant change in cortisol concentrations and no significant variation in behaviours during the presep and postsep periods. Differences arose in the prejoin period with IS sows spending more time eating and drinking and postjoin where there were differences in postures and behaviours between the treatments. During the postjoin period IS sows displayed heightened levels of activity. Wattanakul *et al.* (1997) also found that after the separation board was removed, sows stood up and sniffed piglets more frequently. Wattanakul and colleagues (1997) continued observations for an extra hour during rejoining and found that sows tended to lie and rest at the same frequency seen before rejoining. A proposed concern with the IS separation procedure is that once the piglets are rejoined with the sow, the udder nudging and massaging would increase the amount of damage to the udder. However, no significant difference in udder damage was observed between treatment and control groups in the present study and this is supported by Bereveld *et al.* (2007a). In the majority of litters the IS piglets were provided with supplemental milk prior to rejoining and this may have reduced the suckling activity when rejoined. The problem with this consideration is that there are no details as to how many piglets actually consumed the supplemental milk replacer. Further research is required to assess whether supplemental milk provided before rejoining reduces suckling intensity post joining when IS is used.

Increased activity by the sows after rejoining has been shown to have negative effects on nursing frequency, with restless sows nursing less frequently

(Wallenbeck *et al*. 2008) or nursing while standing. Restless sows are more likely to terminate nursing after a shorter period of udder massage (Varlos *et al*. 2002) and sows that nurse when standing reduce the amount of milk available to their piglets, as normal stimulation of the udder is not possible (Jensen *et al*. 1991). In the present study IS sows had significantly more suckling bouts than control sows. This behavior did not change over the experimental period, suggesting that sows did not acclimate to the increased suckling attempts after rejoining by the piglets. It could be assumed that increased suckling bouts are likely to result in "unsuccessful" nursing (nursing bouts within 20 mins of each other) with effects on piglet development (Berkeveld *et al*. 2007a; Spinka *et al*. 1997). While this is possible, other reports have suggested that increased suckling attempts between milk letdown allows for greater milk intake (Spinka *et al*. 1997). This is because a similar amount of milk is let down every 35 minutes and suckling less frequently will not lead to an accumulation of milk at the udder, but a less frequent retrieval of this standard dose (Audist *et al*. 2000). Consequently higher nursing frequency has been found to positively influence piglets' growth (Valros *et al*. 2002). Further research on the impacts of changing suckling behavior on piglet growth performance is required.

Concerns are commonly raised about the welfare implications of abrupt weaning (Weary *et al*. 2008). In the wild, piglets are weaned gradually from the sow allowing for a more gradual transition onto solid feed (Martin 1984; Jensen and Recen 1989). However, in the pig industry it is normal to abruptly wean piglets at three to four weeks of age (D'Eath 2005). This practice results in weaner 'set-back' because of a change in diet and the stress from the mixing with unfamiliar

514 litters (Colson *et al*. 2006; Silerova *et al*. 2010). A change from liquid to solid feed
515 leads to low feed intake predisposing piglets to diarrhoea and consequently
516 weight loss (Madec 1998; McCracken *et al*. 1999). By integrating IS into the
517 production system in an attempt to induce lactational oestrus in the sow, piglets
518 could remain on the sow for a prolonged period of time and become accustomed
519 to a new diet, allowing for a more gradual transition to weaning (Kuller *et al*.
520 2004; Berkeveld *et al*. 2007a). In the present study, this concept is supported by
521 the significantly greater proportion of time that IS piglets spent eating compared
522 to control litters. Berveveld *et al* (2007a) also found that shortly after the onset
523 of IS, eating behaviour of IS piglets was greater than control piglets. Furthermore
524 it has been found in outdoor systems that sows spend more time away from their
525 piglets and nurse less frequently in late lactation, allowing piglets the
526 opportunity to naturally wean onto creep feed (Pajor 2002). A similar situation
527 is created by IS although not voluntarily. While creep feed intake was not
528 determined in the current investigation, other studies have found increased
529 creep feed intake with the implementation of IS (Langendijk *et al*. 2007; Gomez-
530 Carballar *et al*. 2009). A conflicting study determined that separation for seven
531 hours per day for two weeks prior to weaning failed to increase creep feed
532 intake (Millet *et al*. 2007). This discrepancy may arise from the use of different
533 separation techniques. Millet et al (2007) actually removed sows from the
534 farrowing crates and this would not only have inhibited the piglet's physical
535 contact with the sow but also visual and auditory communication. Therefore, the
536 piglets may have been more distressed in this instance, limiting creep feed
537 intake.
538

539 In conclusion, IS for eight hours seven days prior to weaning in this study did not
540 cause alternations to sow or piglet behaviour to a point that would warrant
541 concern. In sows, behavioural changes only occurred post joining, with no
542 behaviourial or physiological differences between the treatments occurring
543 during periods of separation. Once piglets were rejoined, they spent increased
544 time at the udder but this did not lead to increased damage of the udder, which
545 was a major concern within the industry. Separated piglets did have alterations
546 in their behaviours, however, this was not to a point that would raise concern for
547 their welfare as reflected by cortisol concentrations during periods of
548 separation. While behavior did increase at rejoining the heightened levels of
549 activity declined over the period, illustrating no prolonged alteration in piglet
550 behaviour. Surprisingly separated piglets spent a proportionally greater amount
551 of time around the creep feed area which may be advantageous as it allows for a
552 gradual weaning process. Further research is recommended to fully understand
553 the implication of these behavioural changes before piglet separation is
554 recommended as an appropriate method to induce lactational oestrus in
555 primiparous sows and a gradual transition to weaning for piglets.

556

557 ***Acknowledgements***

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561 Evelyn Hall for her assistance with statistical analysis.

562

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690 in Primiparous Sow Responses to Split Weaning. *Reproduction in Domestic*
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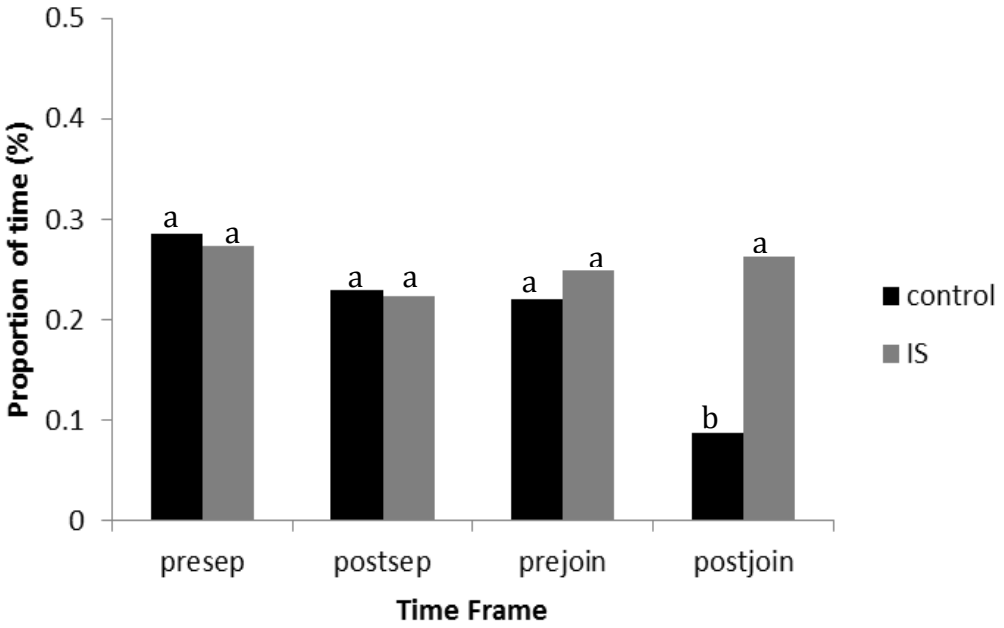
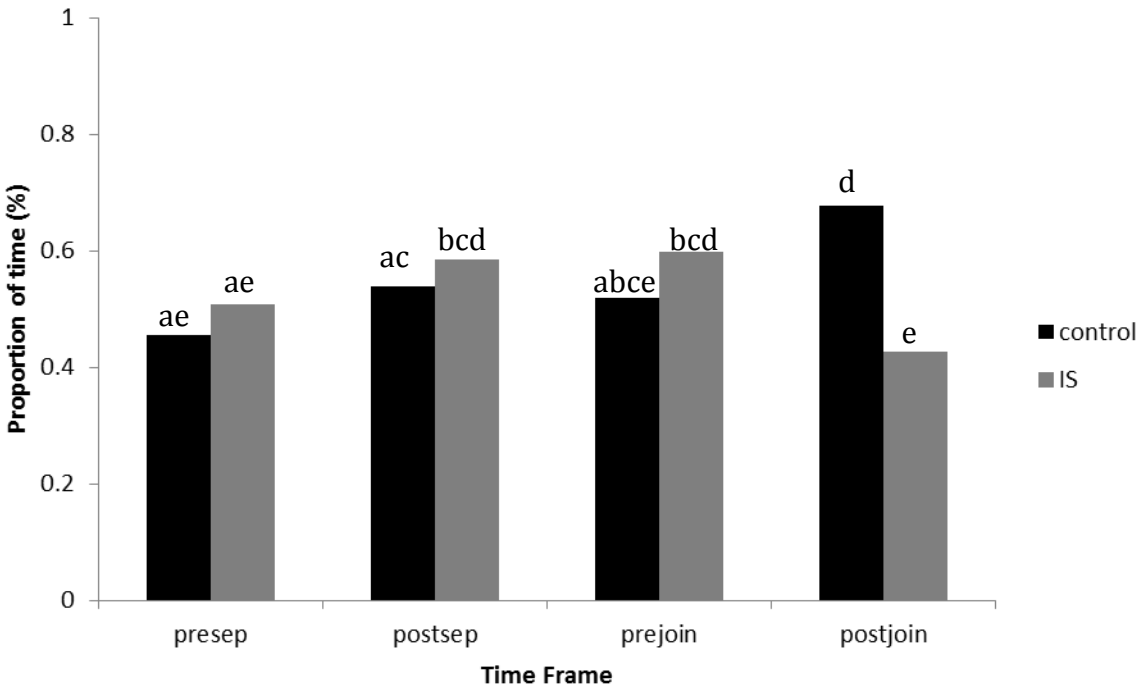


Fig. 1. The proportion of time sows spent standing. Between and within treatments and across time frames values without common superscripts are signficantly differences (P<0.05).



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719 **Fig. 2**. The proportion of time sows time spent resting. Between and within
720 treatments and across time frames values without common superscripts are
721 signficantly differences (P<0.05).

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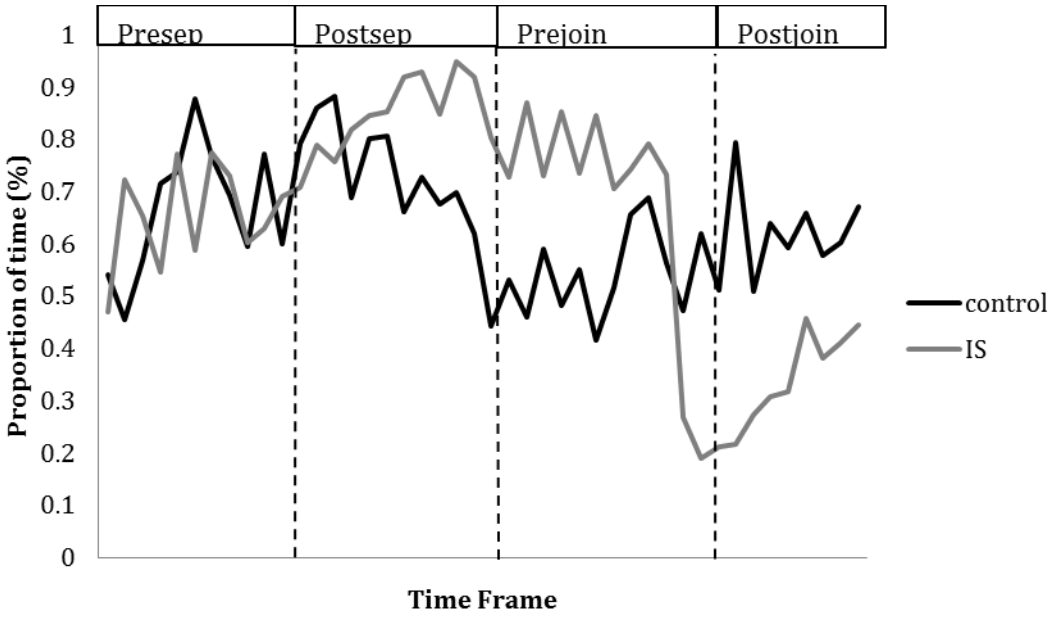

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735 **Fig. 3.** The proportion of time piglets spent lying without sow contact. Each
736 time frame illustrates changes over the hour before separation, one hour after
737 separation, one hour before rejoining and for one hour after rejoining with
738 observations made every five minutes.

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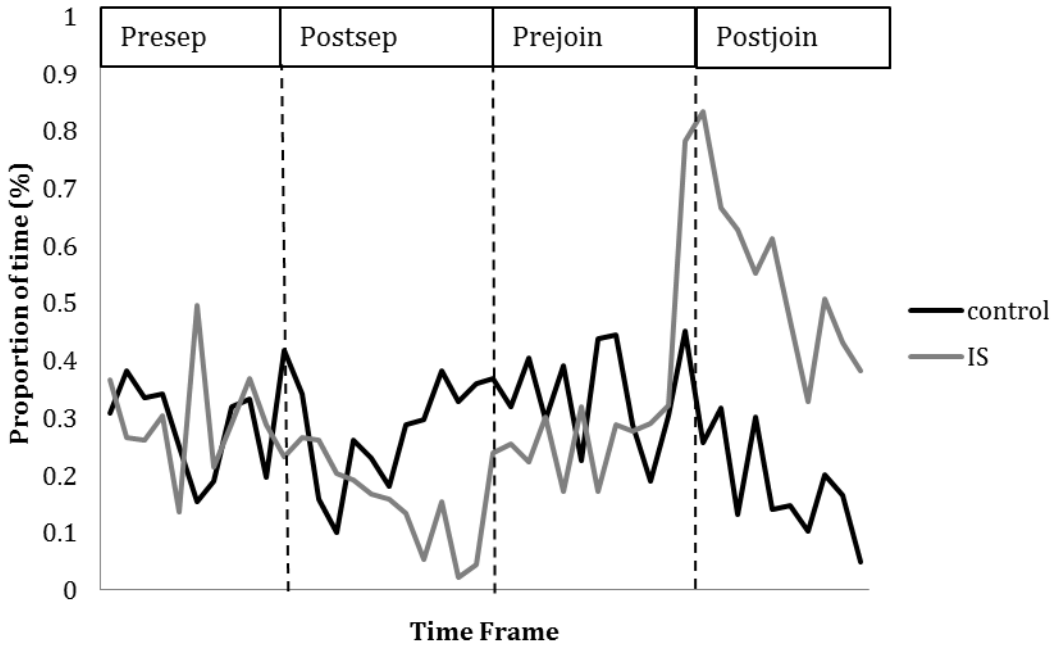
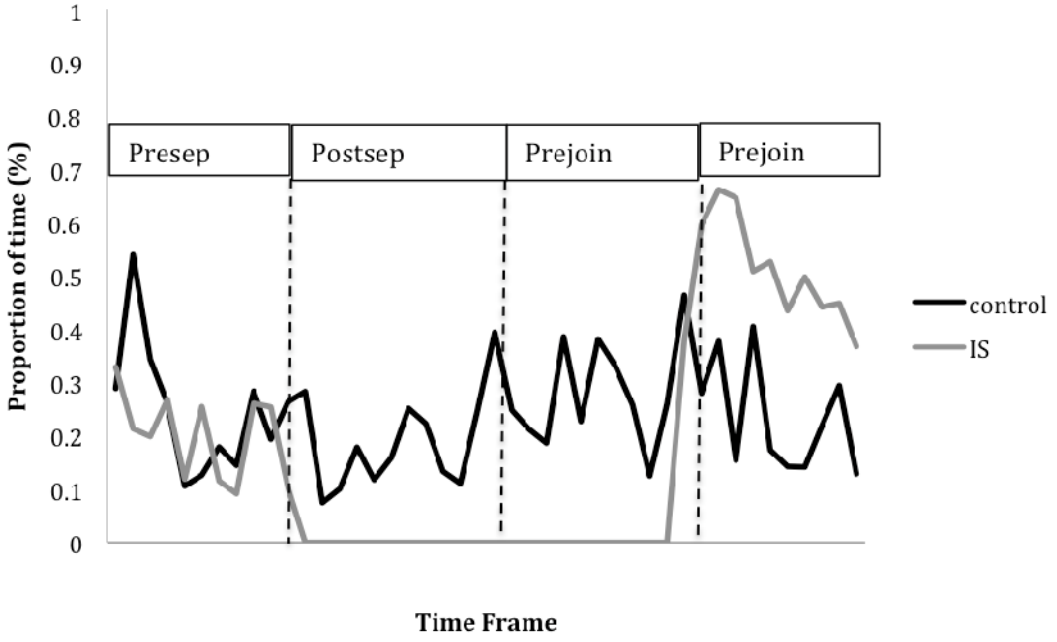


Fig. 4. The proportion of time piglets spent standing. Each time frame illustrates changes over the hour before separation, one hour after separation, one hour before rejoining and for one hour after rejoining with observations made every five minutes.



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767 **Fig. 5**. The proportion of time piglets spent massaging the udder. Each time
768 frame illustrates changes over the hour before separation, one hour after
769 separation, one hour before rejoining and for one hour after rejoining with
770 observations made every five minutes.

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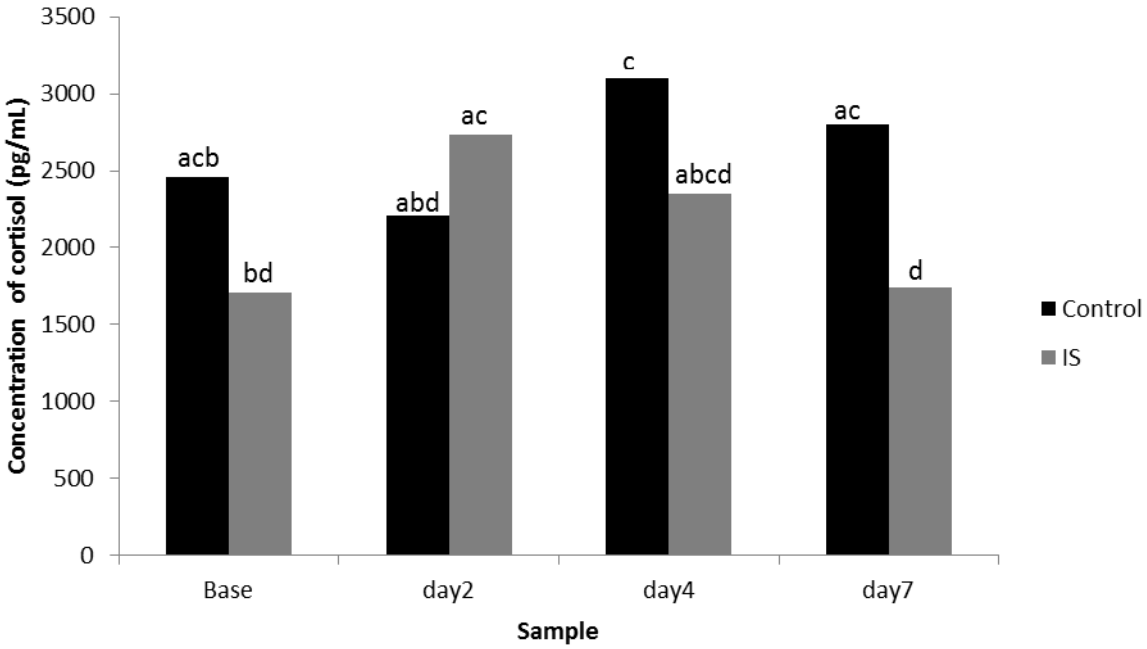

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782 **Fig. 6.** The concentration of cortisol in the saliva on individual sampling days.

783 Between and within treatments values without common superscripts represent

784 signficant differences (P<0.05).

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797 **Table 1**.Ethogram of sow behaviour recorded on days one, three and six.

Behavioural Parameters	Definition
Sow	
Posture	
Standing	Standing on all four feet
Siting	Upper body held up by forelegs and behind resting on floor
Lying	Included both sternal recumbence (lying on the udder) and lateral recumbence (lying on the side)
Activity	
Nursing	Lying of side with udder exposed and piglets nursing
Asleep	Head at rest with no movement by sow, can be lying either on body or on her side
Feeding/Drinking	Eating from the feed bin or drinking for the drinker
Watching	Lying, sitting or standing, showing no other state but visually awake
Looking for Piglets	May be nudging board separating sow and piglets or looking in piglets general direction (only displayed during separation)
Watching piglets / Play with sow	Making contact with piglets or moving head in the direction of piglets for periods of time

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805 **Table 2.** Ethogram of piglet behaviour recorded on days one, three and six.

Behavioural Parameters	Definition
Piglet	
Posture	
Standing	Standing on all four feet
Sitting	Behind resting on floor with upper body held up by forelegs
Lying with sow	Lying in contact with sow
Lying without sow	Lying without sow contact, generally under the lamp
Activity	
Idle	Standing in one place not moving. Can be associated with defecating or urination
Walk/Run	Movement around the pen
Massaging the udder / Nursing	Nursing the udder or visually massing the udder to stimulate milk release
Asleep	Lying without movement
Play/Frolick	Interaction with another piglet , themselves or an object in the pen, such as the feeder
Look for sow	When separated piglets look up at board or jumping on board to try and see the sow
Playing with sow	Piglets interacting the sow
Eating and Drinking	Eating from the provided feeder or drinking from the drinker
Nudging	Nudging the sow in an attempt to get her to nurse. Behaviour could be displayed on any part of the sow's body

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Table 3. The proportion of time sows spent displaying various postures and activities during each time frame. The P values for the highest level significant interaction are given with the abbreviations being ; treatment (T), time frame (t) and minute (m).

Parameter	Treat-ments	Timeframe (%) Presep	Postsep	Prejoin	Postjoin	MST[C]	P value
Sow							
Standing	Control	29.5±3.3	22.6±3.2	21.3±3.0	8.5±2.2	Txt	<0.001
	IS	26.1±3.0	22.2±2.7	24.9±2.8	26.3±2.8		
Lying	Control	70.2±3.8	80.0±3.5	79.0±3.4	91.3±2.4	Txtxm	0.026
	IS	73.9±3.5	74.0±3.3	75.0±3.3	76.0±3.1		
Sitting	Control	7.0±1.7	6.4±1.7	6.0±1.6	4.7±1.5	Txt	0.038
	IS	6.4±1.5	8.7±1.7	5.7±1.4	4.8±1.2		
Nursing	Control	9.7±1.9	8.2±1.8	10.8±1.9	11.5±2.0	txm	0.038
	IS	8.5±1.5	*	*	17.4±2.0		
Resting	Control	45.5±4.1	54.0±4.4	52.0±4.1	67.7±3.9	Txtxm	0.004
	IS	50.7±3.8	58.6±3.6	59.9±3.7	42.7±3.6		
Rubbing	Control	2.8±0.7	2.0±1.0	1.9±1.0	1.4±1.3	Txt	0.03
	IS	0.6±0.5	2.8±1.2	1.3±0.8	1±0.5		
Looking for	Control	*	*	*	*	NA	NA
piglet	IS	*	13.7±1.9	15.1±2.0	*		
Eating and	Control	28.1±3.8	24.5±3.8	19.2±3.3	11.9±2.7	Txtxm	0.032
Drinking	IS	23.9±3.4	24.7±3.3	24.7±3.3	24.1±3.2		
Watching	Control	9.6±2.9	10.4±3.2	11.0±3.2	5.4±1.9	Txtxm	0.003
	IS	12.3±3.3	12.5±3.4	9.9±2.9	4.6±1.6		
Watching/ play with	Control	19.6±2.3	17.1±2.9	19.1±2.8	11.0±2.9	Txt	<0.001
piglets	IS	19.3±3.0	*	*	31.0±2.6		

[B] Standard Error

[C] The highest level significant interaction

* Data could not be collected for these periods as behaviours could not be determined

827 **Table 4.** The proportion of time piglets spent displaying various postures and
828 activities during each time frame. The P values for the highest level significant
829 interaction are given with the abbreviations being ; treatment (T), time frame
830 (t) and minute (m).

Parameter	Treat-ments	Timeframe (%) Presep	Postsep	Prejoin	Postjoin	MST[C]	P value
Piglet							
Standing	Control	29.3±1.6	26.5±1.8	33.5±1.8	19.2±1.8	Txtxm	<0.001
	IS	29.1±1.8	13.7±1.2	25.8±1.6	57.5±1.6		
Sitting	Control	0.4±0.1	0.1±0.1	0.1±0.0	0.1±0.1	t	<0.001
	IS	0.4±0.0	0.0±0.0	0.1±0.1	0.1±0.1		
Lying without the sow	Control	66.8±3.7	75.1±3.0	53.3±3.8	60.5±3.5	Txtxm	<0.001
	IS	65.4±3.2	86.1±2.0	78.0±2.7	30.3±3.4		
Lying with Sow	Control	12.3±4.4	5.9±1.6	24.7±4.1	28.0±2.5		
	IS	14.2±4.0	*	*	25.8±2.7		
Looking for sow	Control	*	*	*	*	Txt	<0.001
	IS	*	4.0±0.7	5.9±0.8	*		
Walking/ Running	Control	5.4±0.6	3.9±0.7	9.0±1.1	3.5±0.8	Txtxm	0.003
	IS	5.1±1.3	2.0±0.4	2.1±0.4	12.5±0.7		
Playing & Frolicking	Control	5.3±.0.5	5.4±1.2	9.2±1.8	1.7±1.2	Txtxm	<0.001
	IS	5.8±2.1	2.3±0.6	5.8±1.2	11.7±1.2		
Nudging	Control	1.9±0.3	2.6±0.6	3.1±0.6	1.2±0.4	Txt	<0.001
	IS	1.8±1.1	*	*	8.6±0.4		
Idle	Control	12.5±0.9	9.9±1.2	16.5±1.4	6.8±1.2	Txtxm	<0.001
	IS	10.5±1.5	6.3±0.8	12.6±1.1	22.4±1.0		
Massaging the udder	Control	25.0±2.6	17.1±2.1	27.5±2.7	25.0±2.6	Txt	<0.001
	IS	19.9±3.1	*	*	50.8±2.1		
Resting	Control	67.6±2.4	76.5±2.3	64.2±2.7	74.2±2.6	Txtxm	<0.001
	IS	72.1±2.7	86.9±1.6	79.1±2.0	36.1±2.3		
Eating and Drinking	Control	2.7±0.5	3.2±0.7	3.6±0.7	1.4±0.6	Txtxm	0.011
	IS	2.3±1.1	6.6±1.0	10.8±1.3	8.4±0.5		
Watching/ Playing with sow	Control	0.7±0.3	1.9±0.6	1.7±0.5	1.0±0.3	T	<0.001
	IS	1.6±1.1	*	*	4.7±0.5		

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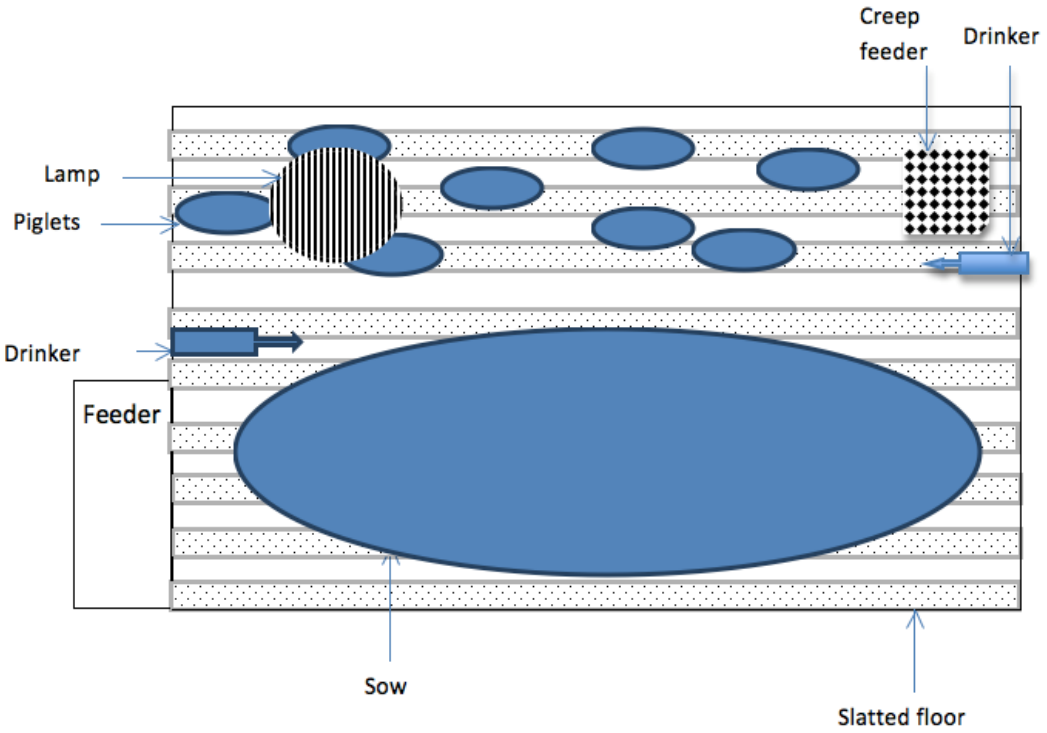
832 [B] Standard Error
833 [C] The highest level significant interaction
834 * Data could not be collected for these periods for these periods as behaviours could
835 not be determined

836 # Appendix



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838 **Diagram.1.** Pen design for the conventional farrowing crate

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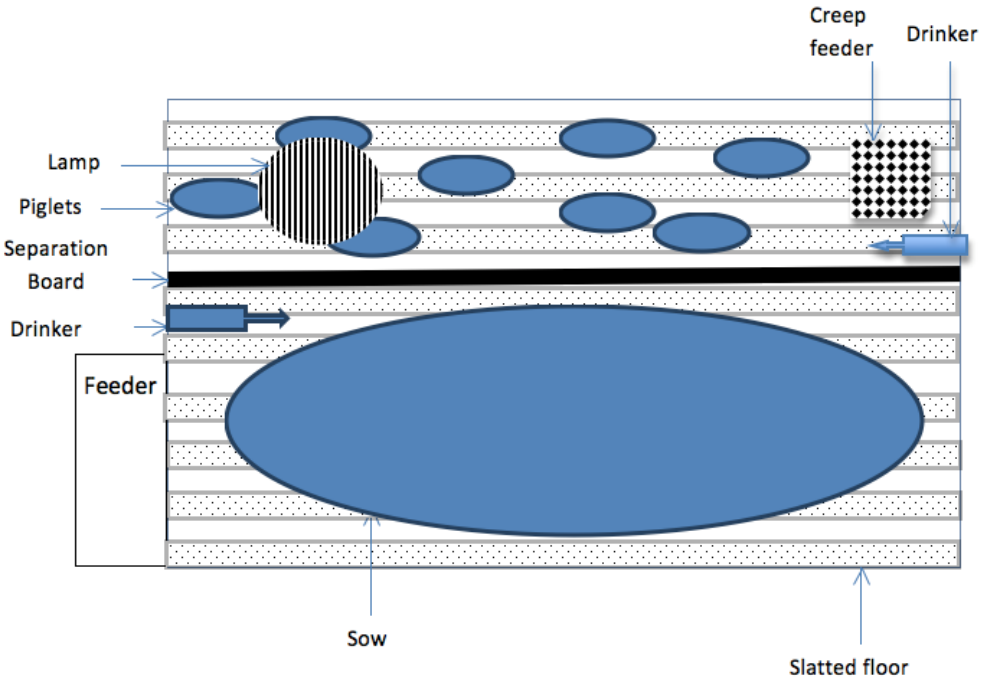

Diagram.2. Pen design during hours of separation with a board present

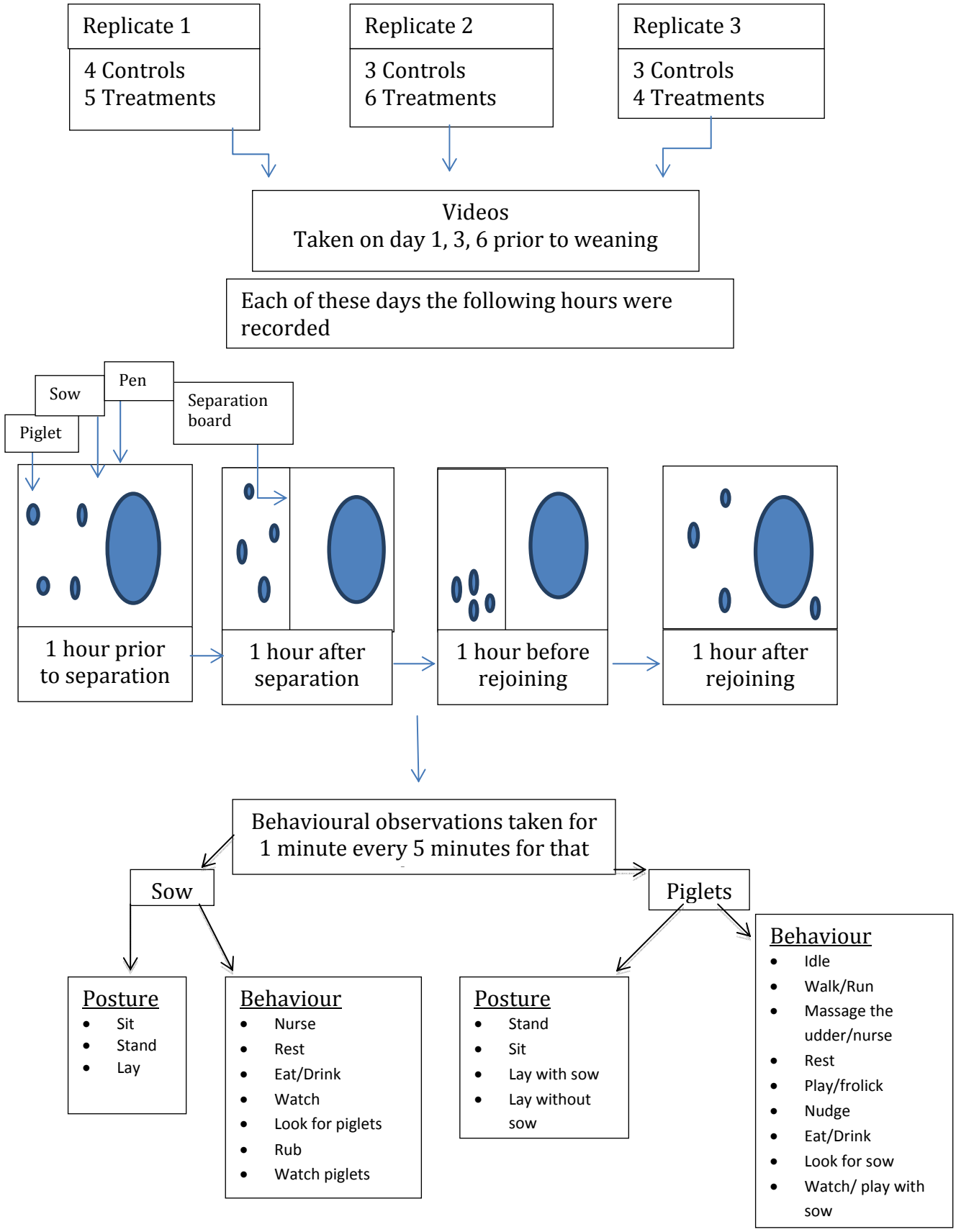

Diagram.3. Video data collection times and the behaviours and activities recorded