Australian Government
Department of Agriculture

AUSTRALIAN Pork™

GDA - Lactation Pens

Final Report
APL Project 2011/2311

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Animal Welfare Science Centre
Jeremy Skuse
The University of Melbourne
Parkville, VIC 3010

1. Acknowledgements

We wish to thank management and staff of Berrybank Farm for their support of this project, in particular, the contribution of Geordie Charles and Sue de Wacht were most valuable.

2. Executive Summary

Data were collected on physical performance of sows and piglets following movement to either a farrowing pen offering the sow over 3m^2 floor space and the option to turn around or a traditional farrowing crate providing the sow 1.2m^2 floor space and no option to turn around.

Further data were collected on costs, labour and OH&S issues associated with the conversion of crates to pens and their operation.

This project complemented a Pork CRC Masters project which investigated sow and piglet behaviour, performance and welfare (Appendix 1).

In summary, it was found that piglet death due to overlay was significantly higher in follow-on farrowing pens compared to follow-on farrowing crates (5.9% vs 2.4%). The cost of converting a traditional farrowing crated pen to a farrowing pen was $3224.50 which included materials and labour. While no obvious OHS issues were reported, time taken to perform piglet and sow treatments in follow-on farrowing pens was approximately 25% - 35% longer than when performed in traditional farrowing crates and time taken to pressure wash each follow-on farrowing pen was approximately 30% longer than the time taken to pressure wash each traditional farrowing crate and pen.

3. Background to Research

The Australian Pork Industry is proactively investigating confinement free systems for lactating sows under the CRC for High Integrity Australian Pork Subprograms 1A (Mating and Lactation Innovations) and 1B (Innovative Weaning Systems).

While CRC funded research is continuing on the application of commercially available farrowing pen designs, Australian Pork Limited, through its Group Demonstration Award program, sought to examine the performance of farrowing pens which had been converted from traditional farrowing crates.

4. Objectives of the Research Project

The current project sought to:

i. Assess the viability of improving welfare conditions for lactating sows by eliminating farrowing crates during the last three weeks of lactation. This will be achieved by moving both sow and litter from the traditional farrowing crate (providing 1.2 m^2 floor space to the sow) on day 4 of lactation to the alternative freedom farrowing pen (which provides over 3 m^2 of space and allows the sow to turn around) and

ii. Provide a site for demonstrating this technology to encourage inspection and adoption by other producers.

5. Introductory Technical Information

The use of confinement housing for reproductive sows in the pig industry is a contentious animal welfare issue. In recent years, public and consumer pressure has driven a shift away from the use of such systems, with many countries introducing legislation to ban or limit the time that sows spend in physically and behaviourally restrictive environments. The use of gestation stalls has been banned in several European countries with a European Union (EU) wide ban to be implemented in 2013 (Council of Europe 2001). In Australia, gestation stalls will be phased out by 2017 (PISC 2008). However the use of sow crates for farrowing and lactation is still standard practice in Australia and are used by 95% of pork producers in the major pig producing countries of the EU (Johnson & Marchant-Forde 2009). The conventional farrowing crate severely restricts the movement of sows and was designed partly for ease of management but primarily to minimise the incidence of piglet crushing (Edwards 2002), which remains the most significant cause of early piglet death in all housing systems (Marchant et al. 2000).

The long-term projection in the pig industry is movement toward totally confinement-free systems, which provide a social and physical environment that enables reproductive sows and their litters to fulfil their natural behavioural motivations. However, in eliminating the use of farrowing crates, it is essential that the benefits they provide in terms of preventing piglet crushing and ease and safety of management are not lost. Various new designs have been trialled (e.g. Baxter 1991; Bøe 1993; Cronin, Simpson & Hemsworth, 1996). These pen designs were developed for use during farrowing and the whole of the lactation period. However they are typically expensive to install, costly in terms of space and require increased labour and specific management skills (Baxter, Lawrence & Edwards 2011a). Over the first few days of piglet life it is essential that humans are able to safely access animals when necessary. It is also the period in which piglets are most vulnerable to crushing by the sow. Retaining the use crates for farrowing and those first critical days may present an opportunity to improve welfare during lactation without risking an increase in piglet losses. A system that restricts the use of farrowing crates to parturition and the first few days of piglet life but uses alternative housing for the majority of the lactation period may be a valuable intermediary setup before transitioning to a totally confinement-free system, allowing design and management factors to be further improved. Converting to any new farrowing/lactation housing system will be costly and must be justified in terms of improvement to animal welfare without compromising productivity. There has previously been some discrepancy between experimental and industry obtained data on piglet survival in alternative systems (Baxter, Lawrence & Edwards 2012). The need for thorough assessment prior to implementation is therefore vital.

This project complemented a Pork CRC Masters project which investigated sow and piglet behaviour, performance and welfare (Appendix 1).

6. Research Methodology

Production data

Data records were collected from the standard production records kept by piggery staff. Piglet mortality data were available from July 2011 until March 2013 representing a total of 616 litters. All these litters were farrowed in farrowing crates where the sows and piglets remained for the first 3 days of lactation and underwent normal management practices. On day 4 sows and piglets were moved to one of two lactation treatments, lactation crates (393 litters) or lactation pens (223 litters). Lactation crates are the same as standard farrowing crates with the crate area (1.9 x 0.6m) for the sow within the total pen floor space of 1.9 x 1.5m. The farrowing pen (freedom farrowing pen) has a total area of 1.8 x 2.5m.

Litter weight data were collected as a total litter weight at weaning on a select number of litters from both lactation crates (12 litters) and lactation pens (28 litters). In addition, to look at the effect of lactation housing system on return to oestrus, date of first service after weaning was included where available. Monitoring of subsequent performance was beyond the scope of this project.

Data analysis

Data were analysed using analysis of variance in the statistical software package SPSS (IBM). In addition to the two lactation pens, parity and season were also examined as fixed factors. Required data were arcsine transformed to meet the assumption of normality. Piglet mortalities and thus number of piglets weaned were affected by the number of piglets in the litter, as such the variable "piglets available" was included as a covariate in the analyses conducted on the lactation accommodation. "Piglets available" was the number of piglets moved to the new lactation accommodation in each litter and was calculated as piglets born alive plus/minus fostering minus mortalities in first 3 days of lactation.

7. Discussion of Results

7.1 Farrowing accommodation - Day 1 - 3 of lactation

As the lactation treatments were imposed from day 4 onwards of lactation, this period will be the focus of the discussion of the results. However, it is important to note that although sows could not be randomly selected for treatment, sows were selected at day 4 in the morning, allocated to treatment and transferred to treatment.

There were no significant differences in the average parity of the sows in each of the lactation treatments nor were there any significant differences between lactation treatments in overall piglet mortalities or causes of mortalities prior to the move to lactation accommodation.

Despite all sows being in farrowing crates for the first three days of lactation, the largest cause of piglet mortalities during this period was overlays by sows followed by low viability of piglets (Figure 1).

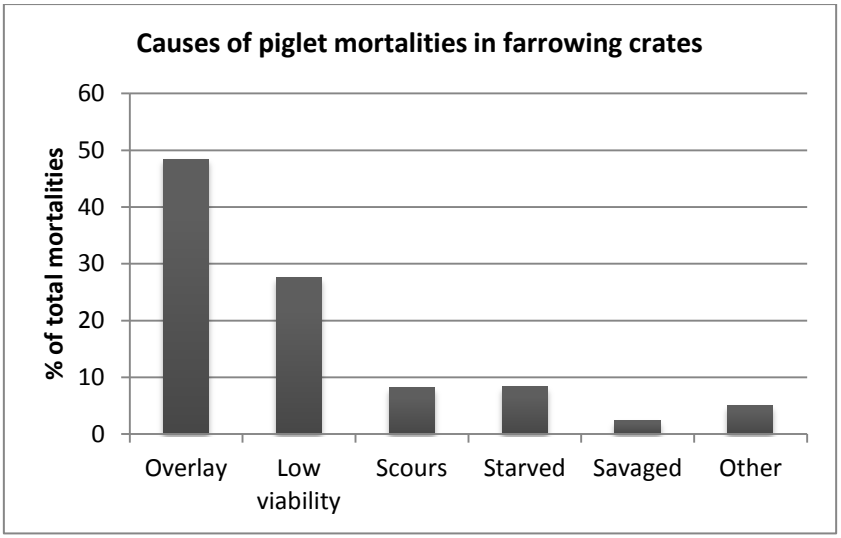

Figure 1: Causes of piglet mortalities in farrowing crates during the first three days of lactation. Mortalities represented as a percentage of total mortalities that occurred during the first three days post farrowing i.e. prior to being moved to lactation accommodation treatments

7.2 Lactation accommodation – day 4 of lactation to weaning

7.2.1. Piglet survival

Overall there were significantly ($p<0.001$) more piglets weaned from lactation crates than from the lactation pens, 10.1 versus 9.8 piglets per litter respectively. The difference in piglets weaned can be explained by the higher mortality seen in lactation pens, with 6.7% of the piglets moved to lactation pens being recorded as mortalities versus 3.7% in crates. The major cause of mortalities in each system was overlays with significantly more overlays occurring in pens than the crates (Table 1). There were no significant differences across any of the other causes of piglet mortalities.

One obvious confounding factor which may have influenced the piglet mortality due to overlays was flooring type. The farrowing crates were fitted with weld mesh flooring while the farrowing pens were fitted with plastic (Mik) flooring (Figure 2).

As stated by Barnett et al, (2001) in their review of welfare issues for sows and piglets in relation to housing, the profile of the flooring used may influence the ability of the sow to change from a standing to lying position in a controlled manner. Farm staff at Berrybank Farm reported that the plastic flooring did not appear to be as effective in providing a slip resistant surface as the weld mesh and thus may have contributed to the greater incidence of overlain piglets in the pens.

Figure 2: Layout of farrowing pens

Table 1: Effects of lactation system, crates (393 litters) versus pens (223 litters) on piglet mortalities once sows and litters have been moved to lactation accommodation (day 4 of lactation to weaning). Arithmetic means (+ standard error of means in parenthesis) provided. Analysis of variance conducted with number of piglets moved as a covariate

Piglets per litter	Crates	Pens	P value
Piglets weaned	10.1 (0.036)	9.8 (0.048)	<0.001
Piglet mortalities as percentage of piglets available	3.7 (0.3)	6.7 (0.4)	<0.001
Piglet mortalities due to overlay as percentage of piglets available	2.4 (0.3)	5.9 (0.4)	<0.001

Seasonal and parity effects on piglet mortality were also found but there were no interaction effects between season and treatment, nor between parity and treatment. The highest number of piglet mortalities occurred in summer (5.2%) whilst the lowest mortalities were observed in autumn (2.9%) (Figure 3). Parity effects are shown in figure 4 with parity 2 sows representing the highest level of mortalities as a percentage of available pigs, 6.8%.

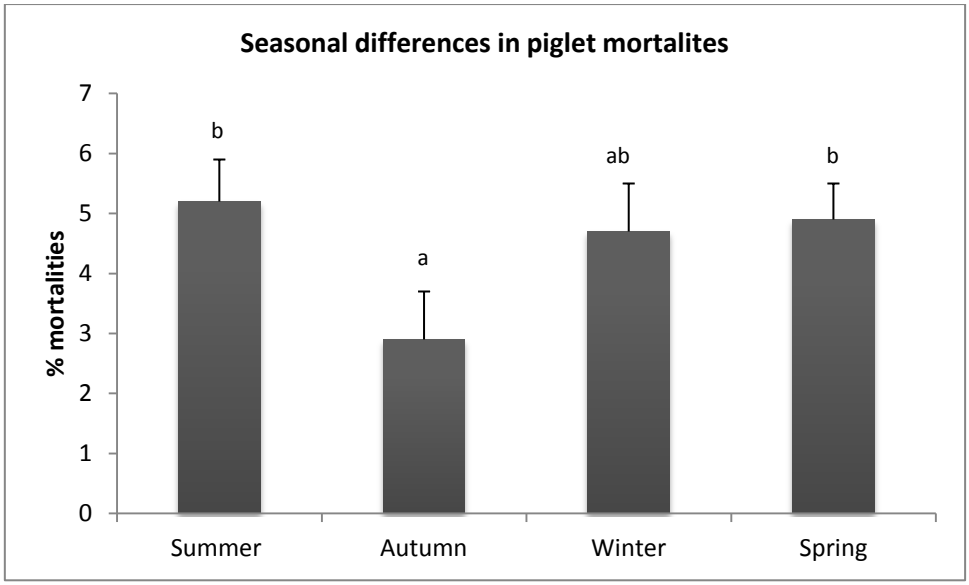

Figure 3: Seasonal differences in piglet mortalities as a percentage of piglets available. Arithmetic means presented with standard error of the mean as error bars. Different superscripts (a, b) differ at P <0.05 level of significance

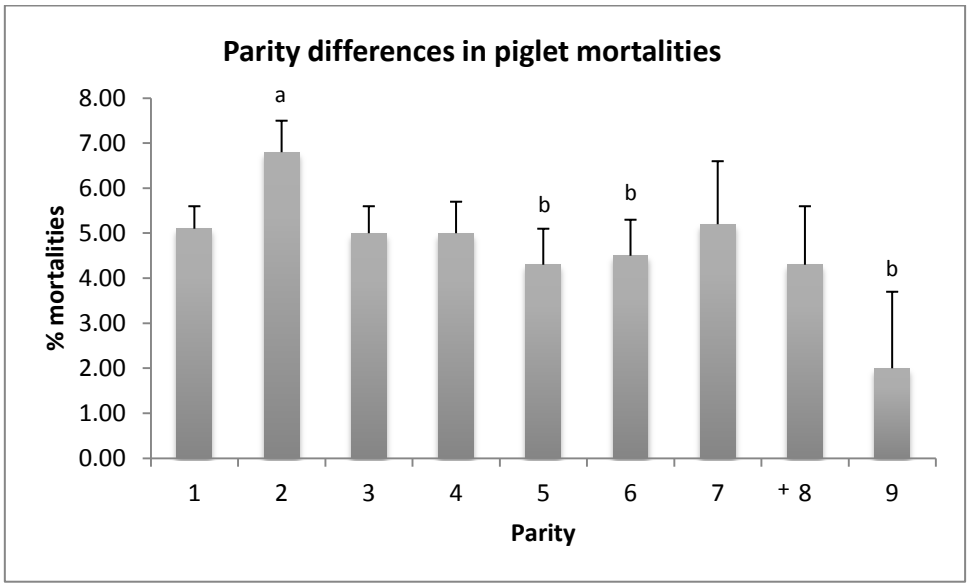

Figure 4: Parity differences in piglet mortalities as a percentage of piglets available, Arithmetic means presented with standard error of the mean as error bars. Different superscripts (a, b) differ at P <0.05 level of significance

7.2.2. Piglet weight gain

Only a small number of litters were weighed at weaning and of those more litters came from pens than crates. There were no significant effects of lactation treatment on overall litter weight and average piglet weight (Table 2). Birth weights were not recorded, but if we apply an assumed birth weight of 1.2kg for all piglets, we can gain an estimate of average piglet weight gain per day, this tended to be higher in the lactation pens than the crates but was not significant (P = 0.073). Sows in lactation pens were weaned on average 1 day earlier than those in crates. This is most likely a product of the management routine of the farm more broadly, however, as there was no negative

effect on litter weight it would be interesting to look more closely at weight gain per day in piglets in each of the systems. A larger sample of litters weighed would be beneficial in extending these observations.

There were insufficient data on subsequent or previous farrowing performance for a robust analysis of either the effects of experience within the lactation system or the effects on future reproductive performance. From the data available, there was no lactation treatment effect ($p>0.05$) on the wean to service interval (Table 3).

Table 2: Effects of lactation system, crates (12 litters) versus pens (28 litters) on litter weight, average piglet weight and average piglet daily gain, mean values presented with standard error of the mean in parenthesis

Variable	Crates	Pens	P value
Litter weight at weaning (kg)	65.083 (3.26)	62.571(2.14)	0.523
Average piglet weight at weaning (kg)*	6.537 (0.363)	6.778 (0.238)	0.582
Average piglet weight gain per day (kg)#	0.194 (0.012)	0.220 (0.008)	0.073

***** calculated using the total litter weight at weaning divided by number of piglets weaned.
# assuming an average birth weight of 1.2 kg and accounting for days of lactation

Table 3: Effects of lactation system, crates (228 sows) versus pens (105 sows) on wean to service interval in days

Variable	Crates	Pens	P value
Wean to first service interval days	6.5	5.5	0.345

7.2.3. Cost

The cost of converting 28 crates to follow-on farrowing pens was recorded by Berrybank Farm. Recorded costs included material costs, (concreting for drainage, flooring, penning, drinking plumbing, flushing plumbing, re-wiring heater lamps, internal pen fittings, painting and re-modelling existing 14 lactation pens) and labour costs associated with the conversion.

Materials	$32,260	
Labour	$58,025	(2,321 hrs @ $25/hr)
TOTAL	**$90,285**	**($3224.50 per pen)**

7.2.4. Labour issues associated with operating follow-on farrowing pens

Berrybank Farm estimates that the time taken to perform piglet and sow treatments in follow-on farrowing pens is approximately 25% - 35% longer than when performed in traditional farrowing crates and pens.

The time taken to pressure wash each follow-on farrowing pen is approximately 30% longer than the time taken to pressure wash each traditional farrowing crate and pen.

No real OHS issues were encountered but farm staff needed to be more aware of the sow's behaviour, especially at weaning.

8. Implications and Recommendations

This study focused on piglet mortalities from day 4 as a measure of both piglet welfare and the performance of the system. This approach had the advantage of being easily recorded from standard production data collected within the piggery. It also served to provide a reasonable estimate of the differences in production output in terms of piglets weaned. Mortalities alone are a crude and limited measure of the welfare performance of a system, however if piglet mortality from day 4 is high, piglet welfare is likely to be at risk.

With the limitations of the present data set in mind we can summarise the major findings around piglet mortality. Based on piglet mortalities lactation crates performed better than lactation pens, with more piglet deaths occurring as a result of overlays in the lactation pens than in the lactation crates.

Due to multiple confounding factors such as flooring type, pen design and lack of a closely-controlled method, it would be unwise to conclude that farrowing pens are necessarily detrimental to piglet mortality. Indeed current research both in Australia and overseas has shown that performance in farrowing pens can be on par with performance from farrowing crates and depends on design of pen, use of bedding, the sows' experience of the system and the skill and dedication of the stockperson (Animal Welfare Science Centre Seminar Sept 2010).

Although not significant, piglet weight gain per day tended to be higher in the lactation pens than the crates. Pedersen et al (2011) compared nursing-suckling behaviour and piglet weight gain in farrowing crates and farrowing pens. They found that piglets reared in farrowing pens had a heavier weight at 28 days than piglets reared in the farrowing crate. The authors concluded that this increase in piglet weight was most likely due to a higher piglet milk intake through improved access to the udder in the farrowing pens.
It has been suggested that a greater interaction between sows and piglets may facilitate social learning, assisting piglets in the transition from milk to solid feed (Oostindjer et al. 2011) and the Pork CRC Masters project (Appendix 1) reported higher level of sow-piglet interactions around suckling in farrowing pens. Berrybank Farm introduce creep feed in feeders to the piglets at around 14 days of age and this increased level of sow-piglet interactions may have stimulated a higher creep intake in piglets housed in farrowing pens which may have contributed to a greater weight gain in piglets. It is recommended that further research should be conducted to investigate the transition from milk to solid feed in piglets reared in farrowing pens.

Current Pork CRC research is investigating the practical use of commercially available farrowing pens and piglet performance will be reported at the conclusion of this research.

Labour associated with treating piglets and sows and cleaning between batches was considerably greater in the farrowing pen treatment. The magnitude of the increase in labour is surprising and may have a large effect on labour costs for farms which utilise farrowing pens. This aspect of the management of farrowing pens warrants further investigation under controlled conditions to contribute to a full financial analysis of the operation of farrowing pens.

9. Intellectual Property

Information generated at this stage of the RD&E process, while creating intellectual property value, does not lead to patentable outcomes.

10. Technical Summary

The information developed by the current project includes;

- An indication of capital cost required to convert a traditional farrowing crate and pen to a farrowing pen.
- An indication of OH&S and labour issues relating to operating a farrowing pen.
- A comparison of physical performance of sows and piglets housed in a farrowing pen versus a traditional farrowing crate and pen from 4 days post-farrowing to weaning at c. 28 days.

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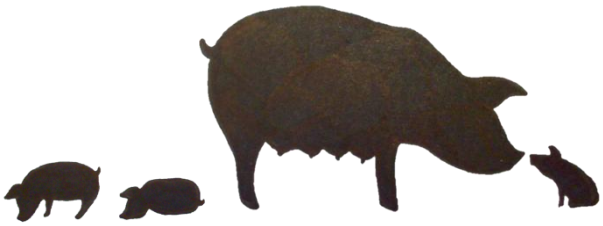
12. Publications Arising

Not applicable.

Appendix 1

Welfare and productivity of sows and litters housed in farrowing pens compared to farrowing crates



Clara Singh

Supervisor: Professor Paul Hemsworth

Contents

Abstract

The use of confinement housing in the pig industry is a contentious animal welfare issue and is beginning to be phased out in many countries. However the use of sow crates during farrowing and lactation is still standard practice and alternatives that improve welfare without compromising productivity and ease of management are under development. A simple loose pen design was trialled alongside a conventional crate system for the period of lactation beginning three days post farrowing and measurements made relating to sow and piglet behaviour, welfare and productivity.

32 sows and their litters (a total of 343 piglets) were studied, with behavioural data recorded weekly over the three weeks of lactation. The two housing systems were compared for piglet survival and weight gain, sow and piglet skin injuries, suckling behaviour and piglet time budgets of behaviour. Frequency, duration and interval between each suckling bout were recorded as well as the frequencies of sow-piglet interaction, displacement at the udder and number of piglets missing each bout. Piglet time budgets of behaviour were observed using instantaneous scan sampling, recording investigatory and social piglet behaviour including close contact with sow and play behaviour.

No significant differences were found in piglet survival ($P=0.20$) or weight gain ($P=0.53$) between treatments. Sows in farrowing pens obtained significantly more skin injuries than those in crates ($P=0.03$) but treatment had no effect on incidence of skin injury for piglets ($P=0.08$). Suckling bout duration ($P<0.01$) and frequency ($P<0.01$) decreased with week while intervals between bouts increased ($P<0.01$) but showed no difference between treatments. Overall, more sow-piglet interaction around suckling was observed in farrowing pens ($P<0.01$), the frequency of which also decreased with week (<0.01). Farrowing pens were also associated with more displacements ($P=0.04$), more piglets missing bouts ($P<0.01$) and fewer bouts terminated by the sow ($P=0.05$). Piglet time budgets of behaviour revealed significantly more play behaviour ($P=0.03$) and interaction with the sow ($P=0.02$) occurring in farrowing pens and more manipulative behaviour ($P=0.02$) and inactivity ($P=0.02$) in farrowing crates.

In summary, farrowing pens appeared to provide more social and environmental stimulation for piglets, resulting in more activity and social interaction, which may be interpreted as an improvement to welfare. The increased incidence of sow skin injuries may indicate a lack of adaptation or experience of sows in the farrowing pen environment. Evaluation of productivity was inconclusive because of the limited sample size.

1. Introduction

Confinement housing for reproductive sows

The use of confinement housing for reproductive sows in the pig industry is a contentious animal welfare issue. In recent years, public and consumer pressure has driven a shift away from the use of such systems, with many countries introducing legislation to ban or limit the time that sows spend in physically and behaviourally restrictive environments. The use of gestation stalls has been banned in several European countries with a European Union (EU) wide ban to be implemented in 2013 (Council of Europe 2001). In Australia, gestation stalls will be phased out by 2017 (PISC 2008). However the use of sow crates for farrowing and lactation is still standard practice in Australia and are used by 95% of pork producers in the major pig producing countries of the EU (Johnson & Marchant-Forde 2009). The conventional farrowing crate severely restricts the movement of sows and was designed partly for ease of management but primarily to minimise the incidence of piglet crushing (Edwards 2002), which remains the most significant cause of early piglet death in all housing systems (Marchant et al. 2000).

Behavioural restriction and sow and piglet welfare

Welfare concerns associated with the use of farrowing crates are largely based on the physical and behavioural restriction of sows, which prevents expression of sows' natural behavioural repertoire. Pigs are naturally active and gregarious animals and in the wild will forage over large home ranges. Wild female pigs typically live most of their life in small groups made up of related individuals of several generations. Just prior to parturition, however, sows will leave their group to seek a safe and isolated area to build a nest for farrowing and nursing their piglets before re-joining the group some days later (Gonyou 2001). Maternal behaviour evolved to favour piglet survival and maturation through provision warmth and nourishment, protection from predators and vertical social learning. Sow crates used during farrowing and lactation in intensive piggeries prevent sows from satisfying many maternal motivations by severely restricting their capacity to move around, interact with their piglets and the environment and stand and lie comfortably. Research has shown that sows restrained in crates direct less behaviour toward their piglets, vocalise to piglets less and are less responsive to piglet vocalisations (Cronin, Simpson & Hemsworth 1996). Some aspects of maternal behaviour may be considered unnecessary under human care (for example nest building, protection of piglets from predators and provision of warmth where heat lamps are provided) and probably for that reason have previously been ignored in the design of modern housing for intensively farmed farrowing and lactating sows. Despite this, domesticated sows have retained strong motivations to perform such behaviours and given the opportunity will display protective maternal behaviour, forming strong and lasting bonds with their offspring (Gustafsson et al. 1999), the prevention of which has implications for sow welfare (Dawkins 1988). It is also becoming apparent that piglets reared with confined sows may be deprived of some benefits relating to social learning and development (Oostindjer et al. 2010; Oostindjer et al. 2011a). These issues have prompted development of alternative farrowing and lactation housing designs that provide greater space allowance and increased behavioural opportunities for sows and piglets.

Housing during the lactation period must consider the physical and behavioural needs of both the lactating sow and her young piglets. These needs differ significantly and housing system design does involve some trade-off between the two (Baxter, Lawrence & Edwards 2011b). Increasing space allowance may improve sow welfare by enabling sows to turn around, lie down more comfortably and display more maternal behaviour but can simultaneously increase the risk of piglet crushing. Earlier comparative studies have shown increased rates of mortality in loose farrowing pens compared to crates (Barnett et al. 2001; Edwards & Fraser 1997). The survival of piglets during lactation is a major consideration both in terms of welfare and productivity; their primary needs being warmth, access to udder (enabling adequate milk intake) and protection from crushing. However increasing space allowance for sows may not necessarily compromise piglet survival. With improvement in pen designs, such as the incorporation of anti-crushing bars and improved flooring materials, some more recent studies have shown similar mortality rates to those achieved in crated housing (Cronin et al. 2000; Gu et al. 2011). It seems that although the risk of death by crushing by the sow tends to be greater in loose-housed systems, piglets reared in crates are at greater risk of death from other causes resulting in overall comparable rates of mortality (KilBride et al. 2012; Weber et al. 2009).

In addition to housing factors, there is large variation in maternal ability between sows due to factors such as age, parity, experience and genetics. These factors seem to interact with environmental factors to influence piglet survival and welfare, with particular behaviours only being expressed under certain conditions (Baxter et al. 2011). The increased space in loose pens enables sows to freely interact with their piglets and display more maternal behaviour, which may produce benefits for piglets. Research has suggested that in some situations, the demonstration of maternal behaviour (eg. nest building activity, response to piglet distress calls, nose contact with piglets during posture changes and restlessness when piglets are removed) is negatively correlated with risk of piglet crushing (Andersen, Berg & Bøe 2005). However mortality alone is a crude measure both of piglet welfare and productivity. By solely focusing on mortality some important factors related to piglet welfare, growth and social development may be overlooked, particularly over the longer term. There is some evidence that roomier pens are associated with longer periods of milk let down, less fighting among piglets and greater weight gain (Pedersen et al. 2011). Greater interaction between sows and piglets may also facilitate social learning, assisting piglets in the transition from milk to solid feed at weaning (Oostindjer et al. 2010).

Alternative lactation housing

The long-term projection in the pig industry is movement toward totally confinement-free systems, which provide a social and physical environment that enables reproductive sows and their litters to fulfil their natural behavioural motivations. However, in abandoning the use of farrowing crates, it is essential that the benefits they provide in terms of preventing piglet crushing and ease and safety of management are not lost. Various new designs have been trialled eg. (Baxter 1991; Bøe 1993; Cronin, Simpson & Hemsworth 1996). These pen designs were developed for use during farrowing and the whole of the lactation period. However they are typically expensive to install, costly in terms of space and require increased labour and specific management skills (Baxter, Lawrence & Edwards 2011a). Over the first few days of piglet life it is essential that humans are able to safely access animals when necessary. It is also the period in which piglets are most vulnerable to crushing by the sow. Retaining the use crates for farrowing and those first critical days may present an opportunity to improve welfare during lactation without risking an increase in piglet losses. A system that restricts the use of farrowing crates to parturition and the first few days of piglet life but uses alternative housing for the majority of the lactation period may be a valuable intermediary setup before transitioning to a totally confinement-free system, allowing design and management factors to be further improved. Converting to any new farrowing/lactation housing system in industry will be costly and must be justified in terms of improvement to animal welfare without compromising productivity. There has previously been some discrepancy between experimental and industry obtained data on piglet survival in alternative systems (Baxter, Lawrence & Edwards 2012). Thorough assessment prior to implementation is therefore vital.

Comparison of two systems

The aim of the present study was to assess the viability (in terms of welfare and production) of replacing the conventional farrowing crate with an alternative system (the farrowing pen) for the lactation period, beginning 3 days post farrowing in a commercial piggery. The farrowing pen being trialled had a slightly increased total floor area, standard heated creep area and sloping bars along two walls. The major differences between the two

housing systems were the increased floor space in the farrowing pens and that sows were unrestrained and could freely walk and turn around.

Assessment of productivity is relatively straightforward and generally based on measurements of litter size, mortality rate, growth rate and sow farrowing rates. In terms of productivity, it was hypothesised that:

1 Piglet survival is unaffected by housing treatment.
2 Piglets housed in pens during lactation gain more weight, producing larger piglets at weaning than those housed in crates.

Evaluation of welfare is somewhat more complex and therefore it is important that multiple, animal-based parameters are used. Due to practicality and lack of consensus on welfare evaluation, it is common in industry to assess animal welfare indirectly, relying on resource and management factors. Animal-based measures can be more difficult and time-consuming to measure in a standardised way but do provide direct evidence of animals' coping success (Barnett & Hemsworth 2009). This approach is underpinned by the definition of welfare described by Broom (2008) who stated that: 'welfare of an individual is its state as regards its attempts to cope with its environment.' Using this definition, observation of abnormal physiological functioning or behaviour may indicate a lack of adaptation or coping success. With the use of physiological measurements of health/fitness complemented by observations of sow and piglet behaviour, welfare assessment during lactation attempts to determine whether the biological and behavioural needs of both the sow and her piglets are being met. Welfare assessment focused on presence of skin lesions, suckling behaviour, frequency of sow-piglet interaction and piglet investigative, social and play behaviour. These were considered to be relevant signs of both sow and piglet welfare.

Assessment of skin injuries has been used previously and can provide evidence of aggression as well as a lack of adaptation to confinement when sows are unable to coordinate their movements in order to avoid injury. For example, the incidence of skin abrasions was found to be higher in gestating sows housed in stalls as opposed to pens (Karlen et al. 2007).

Suckling behaviour is relevant to assessment of both productivity and welfare since adequate milk intake by piglets is vital. Previous studies have found a positive correlation between stability of teat order and growth rate of piglets (Hemsworth, Winfield & Mullaney 1976). Improved access to the udder (as occurs in farrowing pens) has also been associated with increased weight gain and longer periods of milk let-down (Pedersen et al. 2011). Frequency of aggression and interruptions during nursing may also contribute to less effective milk intake by piglets and therefore piglet welfare.

Play behaviour can be used as an indicator of positive welfare (Boissy et al. 2007; Newberry, Wood-Gush & Hall 1988) and may be affected by housing conditions (Chaloupková et al. 2007). Welfare assessment typically focuses on provision of certain requirements and absence of signs of suffering. However the presence of positive indicators of welfare (such as play) are increasingly being recognised as important (Held & Špinka 2011).

By assessment of these welfare indicators, the present study aimed to demonstrate that loose-housing of sows in farrowing pens during lactation enhances welfare for both sows and piglets not only by physical means but by promoting interaction and bonding between sows and piglets.

Relating to welfare, the following hypotheses were tested:

1 Farrowing pen housing during lactation is associated with fewer skin lesions than in farrowing crates for both sows and piglets.
2 Improved social contact and udder access in farrowing pens is associated with more effective nursing with longer suckling bouts, fewer displacements during suckling and fewer piglets missing suckling bouts.
3 Increased area and freedom of movement in farrowing pens provides increased opportunity for sows and piglets to interact during and around suckling bouts resulting in more frequent sow-piglet nose contact.
4 Increased area and freedom for social interaction in farrowing pens results in more frequent investigative, social and play behaviours and less frequent manipulative and aggressive behaviour in piglets.

2. Methods

All animal procedures were conducted with prior approval obtained through The University of Melbourne Animal Ethics Committee.

2.1 Animals and husbandry

Productivity and skin injury assessments were made on 32 sows of mixed parity and their litters (a total of 343 piglets). Each sow and litter unit was randomly allocated to either a control (farrowing crates) or experimental (farrowing pens) treatment group. Twenty-four of the sows and 96 piglets (4 per litter) were observed for behavioural analysis. Focal piglets were selected randomly, balancing for sex and excluding any obvious runts. The study took place at Berrybank Farm, Ballarat, Victoria where all aspects of daily animal husbandry were managed by farm staff according to their normal practice.

2.2 Experimental design

The experiment was run as four identical time replicates (due to small number of available pens) with each replicate consisting of eight sows (four per treatment). All sows were housed in groups during gestation and moved to farrowing crates for parturition. The experimental period began at three days post partum (piglets approximately 3 days of age), when control and experimental sows and their litters were transferred to their respective housing treatments in the lactation shed. They remained there for a further 22-25 days until the piglets were weaned at around four weeks of age.

2.3 Housing treatments

Control sows and their litters were housed in farrowing crates and experimental sows and their litters were housed in farrowing pens in the same shed (see figure 1). The crates and pens were located on the same side of the shed on opposite sides of the aisle. The farrowing crates used were typical of conventional systems, with a space allowance of approximately 1.2m^2 that did not allow sows to turn around. The lactation pens used for the experimental group provided a floor space of over 4m^2. Both physiological and behavioural data relating to productivity and welfare of sows and litters were obtained weekly over the period of lactation.

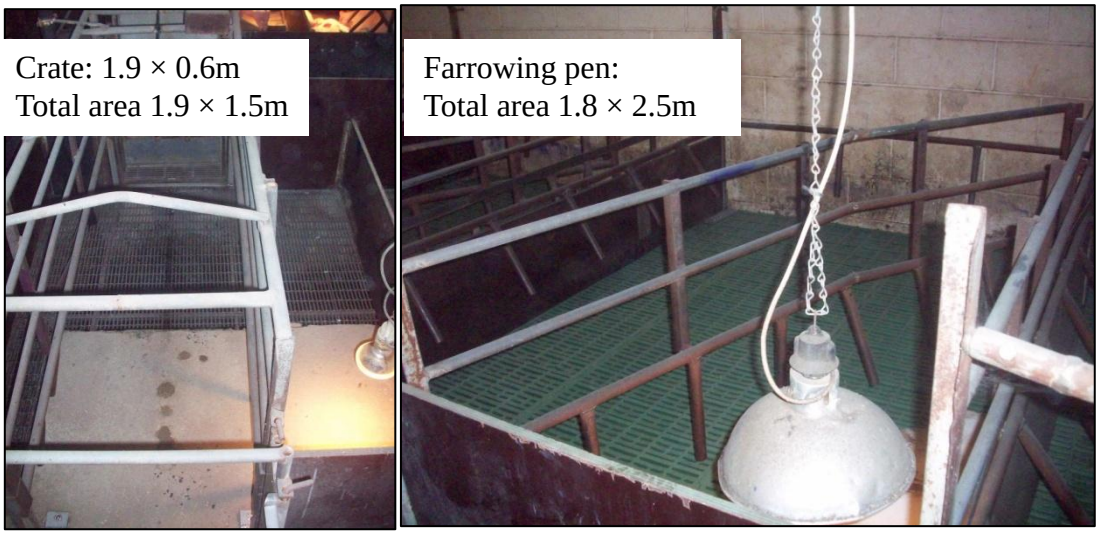


Figure 1 Farrowing crate (left) and farrowing pen (right) design

2.4 Measurement of productivity

The following production data were recorded:

- litter size (ie. no. of piglets alive at beginning of experimental period)
- piglet weight at start of experiment/lactation (approx. 3 days of age)
- piglet weight at weaning
- number of piglet deaths during experiment/lactation

2.5 Measurement of welfare

Data relating to welfare were collected three times for each sow and litter at weekly intervals and consisted of sow and piglet skin injury assessments as well as behavioural observations from video footage.

2.5.1 Skin injuries

Sow and piglet skin injuries were scored using the technique described by Karlen et al. (2007). Only fresh lesions were recorded and these were defined as any injury that appeared red or inflamed indicating it had been obtained recently. Each lesion was described as either a scratch, abrasion, ulcer or cut and further categorised according to location on the body (see figure 2). Injury scores were recorded in the second and third weeks (therefore recording injuries obtained during the first and second weeks) of the lactation period with two assessments made for each sow and focal piglet.

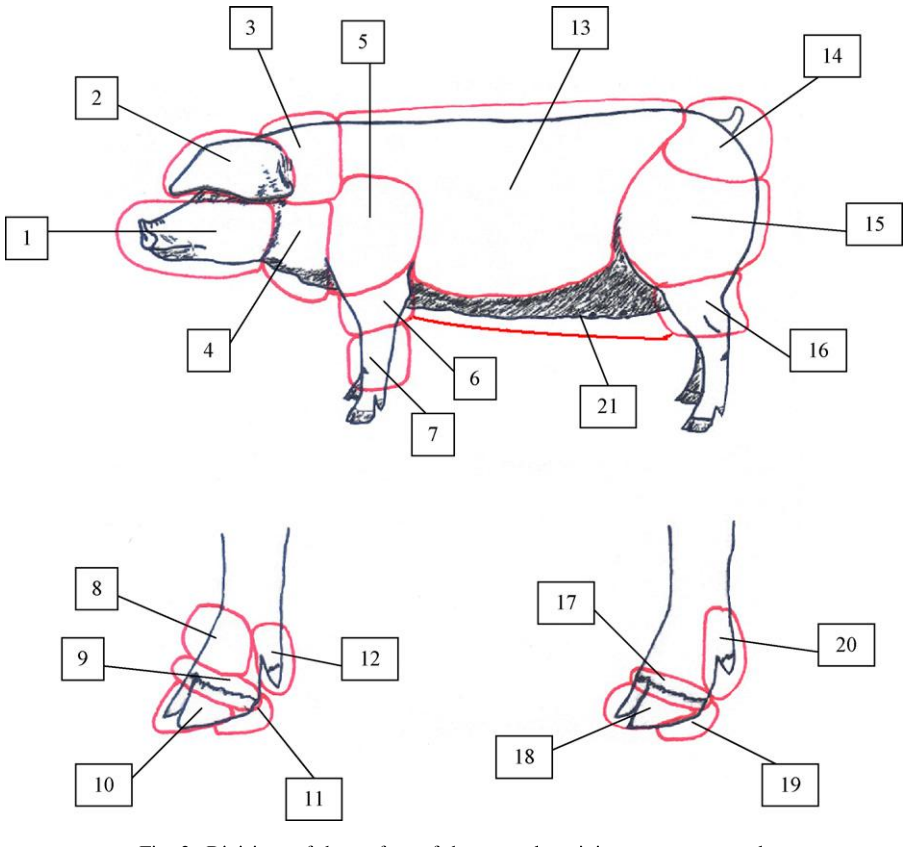


Figure 2 Classification of body regions for skin injury assessment as used by (Karlen et al. 2007)

2.5.2 Behaviour

Sow and piglet behaviour during lactation was recorded using both digital video recorders installed above each pen and a hand-held camcorder. Overhead cameras recorded continuously on the 2nd, 9th and 16th day of the experimental period between the daylight hours of 0700 and 1700 h. This footage was used for quantification of suckling behaviours and sow-piglet interactions around suckling bouts.

Hand-held recordings were obtained on the same days for four hours each day using a scan sampling technique in which pens/crates were filmed for 30s at a time, constantly rotating. Recordings were made for one hour at a time with hours starting at 0800, 0910, 1020 and 1130 h, resulting in a total of 60 30s scans per day per pen/crate. These recording were used to obtain data on piglet behavioural time budgets.

All video footage was viewed retrospectively to quantify the following specific sow and piglet behaviours:

2.5.3 Behaviour: suckling behaviour

The following data was recorded for each suckling bout between 0700 and 1700 h on the 2nd, 9th and 16th day in lactation housing:

- Length of suckling bout

- Termination of suckling: by sow/piglets
- Number of displacements during suckling
- Number of piglets that missed milk let-down
- Number of sow-piglet or piglet-sow (recorded together) interactions for two minutes prior, during and two minutes after suckling bouts.

Table 1 below lists the definitions used to record the above listed parameters.

Table 1 Definitions used for quantification of suckling behaviour observed by video footage.

Suckling bout	A bout of suckling where at least 75% gather at udder and massage/suckle for >1.5min. NB. 75% of piglets was calculated as 7/9, 8/10 or 9/11, depending on number of piglets in litter.
Start of suckling bout	75% of piglets gather at udder and begin massaging.
End of suckling bout	75% of piglets have stopped massaging (became still or moved away from the udder) OR sow terminates massage/suckling by changing posture.
Sow-piglet interaction	Close contact <10cm between sow's nose and piglet body, where sow moves her head to make contact with piglet, pausing and maintaining close contact for >1s. Or Close contact <10cm between piglet's nose and sow's face where piglet moves to make contact, pausing and maintaining close contact for >1s. Interactions were recorded as single events when close contact was observed repeatedly within a period of 5s between the same piglet and sow
Piglets that missed suckling bout	Piglets absent from udder (not suckling/massaging or attempting to) for a majority of suckling bout duration.
Displacement at udder	A piglet is displaced from the udder (becomes detached from the teat and has to walk outside or over the cluster of piglets to claim new position) during suckling bout, when 75% piglets are still suckling/massaging and prior to milk letdown (75% piglets still, finished when first piglets resumes massage). Does not include piglets that leave the udder and do not return immediately and resume suckling/massage

2.5.4 Behaviour: piglet time budgets of behaviour

Activity of each of the four focal piglets from each litter was recorded for each 30s interval to estimate frequencies of significant behaviours as described in Table 2.

Table 2 Definitions of piglet behaviours used to estimate piglet time budgets of behaviour, adapted from the definitions used by Oostindjer et al. (2011c).

Lying/inactive	Lying or sitting, not engaged in activity.
Walking/standing	Standing or walking but not otherwise engaged in activity (includes urinating and defecating).
Suckling/udder massage	Either mouth on teat or nose contact to udder with vertical head movements.
Investigatory behaviours	
– Investigating pen/floor/sow body	Sniffing, touching, biting, rooting, pawing or rubbing any part of the pen, floor or sow's body other than head.
– Investigating food/water	Sniffing, touching, pawing, eating or drinking food or water.
Social behaviours	
– Nosing other piglet	Touching or sniffing any part of the head or nose of another piglet (distance <10cm).
– Manipulative behaviour	Nibbling, sucking, chewing or rubbing with nose any part of the body of another piglet.
– Aggression	Ramming, pushing or biting another piglet.
– Mounting	Standing on the back of another piglet with front legs.
– Play	Shaking head, pivoting, jumping, or running with bouncy or jerky movements.
– Interacting with sow	Sniffing, grunting or nuzzling sow's head with <10cm between piglet nose and sow's head.

3. Data analysis

All data were analysed using the statistical package, SPSS Statistics. Analysis of variance for repeated measures was used to examine between groups (treatment) effects as well as within subject (time) effects on sow and piglet behavioural measures and injury scores. Piglet survival and weight gain data were analysed using univariate analysis of variance. All data were tested for normality prior to analysis and a square root transformation was applied to all data sets that were non-normally distributed.

4. Results

4.1 Measurement of productivity (Table 3)

Analyses of piglet weight gain and survival were conducted on results from litter averages and litters rather than overall means. Piglet daily weight gain and survival were lower for animals housed in farrowing pens compared to crates, however these differences were not significant (P=0.53 and P=0.20 respectively).

Table 3 Effects of housing treatment on piglet daily weight gain and survival during lactation

Main effects	Means		SEM	$F_{1,30}$	P value
	Crates	Pens			
Piglet daily weight gain (g)	240.4	230.4	0.63	0.40	0.53
				$F_{1,30}$	
Piglet % survival/litter*	9.71 *(94.24)*	9.55 *(91.17)*	0.12	1.74	0.20

*Data square root transformed prior to statistical analysis. Back-transformed means are presented in parentheses.

4.2 Measurement of welfare

4.2.1 Skin injuries (Table 4)

Skin injury analysis was conducted using results from individual sows and focal piglets. The incidence of skin injury for sows was significantly higher in pens compared to crates (P=0.03). There was no effect of week (P=0.49) or any effect of a week × treatment interaction (P=0.95). Housing treatment had no effect on the incidence of piglet skin injury (P=0.08) however there were significant effects of both week (P<0.01) and an interaction effect between week and treatment (P=0.01). Piglets had significantly more injuries in the third week of lactation compared to the second and this effect was more pronounced in pens than in crates.

The majority of both sow and piglet skin injuries obtained during the lactation period were minor scratches (sows mean 73% scratches, 21% abrasions and piglets mean 97% scratches). In the piglets, most of these injuries (86%) were on the ears, face, shoulders and neck regions (regions 1, 2, 3, 4 and 5). Sows showed a similar pattern of injuries, with a large proportion (30%) occurring around the face, neck and ears (regions 1, 2, 3 and 4). Neither sows nor piglets in either housing treatment obtained serious injury during the experimental period.

Table 4 Effects of housing treatment on the incidence of sow and piglet skin injury during the lactation period

Main effects	Week	Means		SEM	$F_{1,30}$	P value
		Crates	Pens			
Total new injuries (sows)*	2	0.53 *(0.28)*	1.11 *(1.23)*	0.32	5.05	0.03
	3	0.65 *(0.43)*	1.25 *(1.57)*	0.34		
					$F_{1,124}$	
Total new injuries (piglets)*	2	0.51 *(0.26)*	0.46 *(0.21)*	0.14	3.06	0.08
	3	1.62 *(2.63)*	2.19 *(4.79)*	0.23		

*Data square root transformed prior to statistical analysis. Back-transformed means are presented in parentheses.

4.2.2 Suckling behaviour (Table 5)

Sucking behavioural data were analysed as means per sow/litter unit. Neither the number of suckling bouts, duration of suckling nor duration of the interval between bouts differed significantly between treatments. Week had a significant effect on both the number of suckling bouts ($P<0.01$) and suckling bout duration ($P<0.01$), with the average number of bouts highest in the second week and decreasing in the third week. Accordingly, the duration of intervals between suckling bouts also decreased in the second week and increased again in the third week for both treatments ($P<0.01$). Suckling bout duration declined over time in both housing treatments. No week × treatment interactions were evident for these suckling behaviour variables.

Frequency of sow-piglet interactions occurring during the two minutes immediately prior to suckling was unaffected by housing treatment ($P=0.38$), week ($P=0.93$) or a week × treatment interaction ($P=0.06$). However, interactions during suckling bouts did show a treatment effect with a greater number of interactions observed in farrowing pens ($P<0.01$). Week also showed an effect ($P<0.01$), with the frequency of interactions decreasing over time. There was no interaction effect between week and treatment ($P=0.22$). Interactions observed in the two minutes immediately post suckling showed similar effects; with significantly more frequent interaction in the farrowing pens ($P=0.01$). There was also a significant interaction effect between week and treatment ($P<0.01$) but no overall effect of week ($P=0.88$). The number of interactions observed post suckling in farrowing pens increased with time while those in farrowing crates decreased. When total interactions around suckling were analysed as a single measure (as a sum of pre, during and post suckling interactions), frequencies generally declined over time in both pens and crates ($P<0.01$) but much more substantially in the farrowing crates, showing a significant interaction effect between treatment and week ($P<0.01$). There was also significantly more interaction around suckling occurring in the pens than the crates overall ($P<0.01$).

The number of piglets that missed suckling bouts was higher in farrowing pens than crates ($P<0.01$). This variable also showed a week ($P=0.02$) and a week × treatment interaction ($P=0.04$) effect. The average number of piglets missing bouts generally decreased over time in both treatments but the effect was more pronounced in the crates. Similar effects were seen in the frequency of displacements. Overall, displacements were more frequent in the pens ($P=0.04$) and declined over time in both treatments ($P<0.01$), also showing a week × treatment effect ($P=0.05$), decreasing more rapidly in farrowing pens.

The proportion of bouts terminated by the sow was significantly affected by both housing treatment ($P=0.05$) and week ($P=0.03$). Sows housed in crates terminated a greater proportion of suckling bouts and in both treatments there was an overall increase in that proportion over time apart from a marked reduction in week two in the pen treatment. No week × treatment effect was evident ($P=0.76$).

Table 5 Effects of housing treatment on sow and piglet suckling behaviour

Main effects	Week	Means		SEM	$F_{1,22}$	P value
		Crates	Pens			
No. of suckling bouts	1	14.00	14.92	0.95		
	2	14.67	15.83	0.93	2.28	0.15
	3	12.75	13.83	0.79		
Bout duration (s)*	1	21.48 *(461.36)*	20.19 *(407.53)*	1.19		
	2	19.91 *(396.36)*	19.63 *(385.49)*	0.71	0.80	0.38
	3	17.98 *(323.45)*	17.66 *(311.71)*	0.84		
Bout interval (s)	1	2636	2438	198		
	2	2488	2299	189	2.55	0.13
	3	2867	2654	213		
Sow-piglet interactions 2min pre-suckling*	1	1.27 *(1.61)*	1.18 *(1.40)*	0.15		
	2	1.09 *(1.18)*	1.30 *(1.70)*	0.13	0.80	0.38
	3	1.05 *(1.10)*	1.36 *(1.86)*	0.12		
Sow-piglet interactions during suckling*	1	1.78 *(3.17)*	1.99 *(3.94)*	0.20		
	2	1.32 *(1.74)*	1.88 *(3.55)*	0.15	10.17	<0.01
	3	1.19 *(1.41)*	1.17 *(1.36)*	0.14		
Sow-piglet interactions 2min post-suckling	1	1.77	1.63	0.24		
	2	1.43	1.89	0.27	7.90	0.01
	3	1.09	2.42	0.35		
TOTAL sow-piglet interactions around suckling*	1	2.59 *(6.69)*	2.68 *(7.17)*	0.18		
	2	2.11 *(4.46)*	2.69 *(7.22)*	0.14	13.83	<0.01
	3	1.92 *(3.68)*	2.64 *(6.96)*	0.14		
Piglets missed suckling bouts*	1	1.92 *(3.68)*	2.64 *(6.96)*	0.08		
	2	0.44 *(0.20)*	0.47 *(0.22)*	0.08	12.55	<0.01
	3	0.22 *(0.05)*	0.50 *(0.25)*	0.09		
Displacements during suckling*	1	1.16 *1.36*	1.63 *(2.65)*	0.26		
	2	0.64 *(0.41)*	1.05 *(1.11)*	0.16	4.79	0.04
	3	0.77 *(0.59)*	0.68 *(0.46)*	0.12		
Proportion of bouts terminated by sow*	1	0.68 *(0.47)*	0.60 *(0.36)*	0.07	4.49	0.05

	2	0.68 *(0.47)*	0.55 *(0.30)*	0.06	
	3	0.77 *(0.59)*	0.67 *(0.45)*	0.07	

*Data square root transformed prior to statistical analysis. Back-transformed means are presented in parentheses.

4.2.3 Piglet time budgets of behaviour (Table 6)

Frequencies of piglet behaviours were expressed as proportions, that is, number of times each behaviour was observed divided by total number of observations and the means are given in Table 6 below. Data analyses were conducted on results from individual piglets. Treatment effects were apparent in the frequencies of several piglet behaviours; lying (P=0.02) and manipulative behaviours (P=0.02) were more frequently observed in farrowing crates whereas play behaviour (P=0.03) and close contact with sow (P=0.02) were observed more frequently in farrowing pens. Many piglet behaviours were also affected by week with time spent lying (P<0.01) and suckling/massaging udder (P<0.01) showing a general reduction over time, although in farrowing pens the maximum mean value for proportion of time spent at the udder was calculated for the second week of lactation. Investigatory behaviours of investigating pen (P<0.01) and investigating/eating food (P<0.01) as well as social behaviours of nosing (P=0.03), aggression (P<0.01), manipulative behaviour (P<0.01) and play (P<0.01) all increased over the three observed weeks however investigating/eating food and nosing pen-mates were observed most frequently in the second week. Interaction effects between treatment and week were not apparent for most piglet behaviours, with lying behaviour showing an interaction effect (P=0.02) where lying decreased much more rapidly over time in the pens compared to crates.

Table 6 Effects of housing treatment on frequencies of piglet behaviours between 0800 and 1230 h over three weeks of lactation

		Means				
Main effects	Week	Crates	Pens	SEM	$F_{1,124}$	P value
Lying/inactive*	1	0.79 *(0.62)*	0.79 *(0.63)*	0.01		
	2	0.74 *(0.55)*	0.72 *(0.52)*	0.01	5.78	0.02
	3	0.75 *(0.56)*	0.71 *(0.51)*	0.01		
Walking/standing*	1	0.25 *(0.06)*	0.24 *(0.06)*	0.01		
	2	0.26 *(0.07)*	0.25 *(0.06)*	0.02	0.02	0.89
	3	0.23 *(0.05)*	0.24 *(0.06)*	0.02		
Suckling/udder massage*	1	0.49 *(0.24)*	0.48 *(0.23)*	0.02		
	2	0.48 *(0.23)*	0.51 *(0.26)*	0.01	0.01	0.90
	3	0.46 *(0.21)*	0.46 *(0.21)*	0.02		
Investigating pen/floor/sow body*	1	0.17 *(0.03)*	0.16 *(0.02)*	0.02	0.22	0.64

	2	0.21 *(0.04)*	0.22 *(0.05)*	0.02		
	3	0.23 *(0.05)*	0.24 *(0.06)*	0.02		
Investigating food/water*	1	0.01 *(0.00)*	0.01 *(0.00)*	0.01		
	2	0.57 *(0.33)*	0.27 *(0.07)*	0.01	0.01	0.27
	3	0.11 *(0.01)*	0.11 *(0.01)*	0.02		
Nosing other piglet*	1	0.11 *(0.01)*	0.10 *(0.01)*	0.02		
	2	0.13 *(0.02)*	0.15 *(0.02)*	0.02	2.98	0.09
	3	0.11 *(0.01)*	0.14 *(0.02)*	0.02		
Manipulative behaviour*	1	0.02 *(0.00)*	0.01 *(0.00)*	0.01		
	2	0.08 *(0.01)*	0.05 *(0.00)*	0.02	5.68	0.02
	3	0.06 *(0.00)*	0.05 *(0.00)*	0.02		
Aggression*	1	0.01 *(0.00)*	0.01 *(0.00)*	0.01		
	2	0.13 *(0.02)*	0.11 *(0.01)*	0.02	0.91	0.34
	3	0.13 *(0.02)*	0.18 *(0.03)*	0.02		
Mounting*	1	0.00 *(0.00)*	0.00 *(0.00)*	0.00		
	2	0.00 *(0.00)*	0.00 *(0.00)*	0.01	0.30	0.58
	3	0.00 *(0.00)*	0.01 *(0.00)*	0.01		
Play*	1	0.02 *(0.00)*	0.02 *(0.00)*	0.01		
	2	0.05 *(0.00)*	0.07 *(0.00)*	0.02	4.97	0.03
	3	0.04 *(0.00)*	0.07 *(0.01)*	0.02		
Interacting with sow*	1	0.05 *(0.00)*	0.08 *(0.01)*	0.02		
	2	0.08 *(0.01)*	0.09 *(0.01)*	0.02	6.174	0.02
	3	0.08 *(0.01)*	0.11 *(0.01)*	0.02		

*Data square root transformed prior to statistical analysis. Back-transformed means are presented in parentheses.

5. Discussion

5.1 Productivity

No significant differences in piglet survival or growth were apparent in the present study, although mean piglet daily weight gain and survival were slightly greater in animals housed in farrowing crates. These results support the hypothesis that survival is similar in the two treatments but do not support the hypothesis that growth rate is increased in farrowing pens. However, larger numbers of litters would be necessary to rigorously test these two hypotheses, particularly to test for differences in rates of survival. A tendency for slightly increased mortality rates for piglets reared in farrowing pens has been demonstrated in previous research comparing crated and loose-housed sow systems eg. (Blackshaw et al. 1994; de Oliveira Junior et al. 2011; Glastonbury 1976). Increased space for sows has been associated with greater risk of overlay and chilling of piglets (Edwards & Fraser 1997). However, most research into alternative housing uses sows that have had no or limited prior experience in the new system being trialled. Sow experience could potentially make a significant difference to piglet survival and welfare in alternative systems and this effect has been observed in the trial of a group farrowing system (Wechsler 1996). In the present study it was not possible to control or balance for sows who had reared litters in farrowing pens previously.

Further research is required to examine the effects of both farrowing pen housing and sow experience on sow productivity. Productivity evaluation of large numbers of animals is essential prior to implementation of any new system as even marginal differences in productivity can have a highly significant economic impact on the farm.

5.2 Sow welfare

5.2.1 Injuries

The interpretation of sow skin injury scores with regard to sow welfare requires some knowledge as to the cause and severity of those injuries. When sows are housed individually, skin injuries may be obtained by scrapes or bumps on pen/crate walls or bars and/or from contact with piglets. In the present study, the majority of the sow injuries obtained were minor scratches and abrasions. The difference in incidence of skin injury between housing treatments may reflect a lack of experience of sows changing posture in the farrowing pens, particularly when changing from standing to lying. With a large proportion of injuries present around the sows' faces and necks it is also plausible that the increased interaction with piglets that occurred in the farrowing pens contributed to more scratches, as piglets were observed climbing on, playing with and biting sows, particularly around their ears and face. Although the observed difference in sow skin injuries did not support the hypothesis that injuries would be reduced in farrowing pens, it may not indicate any significant negative impact on the welfare of sows housed in farrowing pens, since no serious injury was observed.

5.2.2 Expression of maternal behaviour

Domestic sows retain many of the behavioural motivations of their wild ancestors and this is particularly apparent during farrowing and lactation. At this time the sow is highly motivated to perform specific

behaviours relating to the care and protection of her offspring including nest-building, farrowing and nursing. Greater expression of maternal behaviour can be associated with improved piglet survival and weight gain but also depends on the environment (Andersen, Berg & Bøe 2005; Arey & Sancha 1996). Sow-piglet interaction seems to be an important expression of maternal behaviour during lactation and is necessary both for recognition of piglets by the sow and to coordinate effective suckling (Algers 1993). Sows mainly rely on olfactory cues to recognise their piglets and will often behave quite aggressively to unfamiliar piglets (Horrell 1982). In the present study, the increased interaction observed between sows and piglets in the farrowing pens (both around suckling and also overall as measured by piglet time budgets of behaviour) provides evidence of behavioural restriction of sows in crates. The frequency of sow-piglet interaction around suckling also decreased less over time and the overall frequency of piglet interactions with the sow increased more over time in the farrowing pens compared to crates, which may be a result of the formation of stronger social bonds between sows and piglets. Sow-piglet nasal contact has also been shown to occur more frequently in wild-type compared to domestic sows and piglets (Gustafsson et al. 1999) suggesting that it is a natural behaviour with some evolutionary advantage.

Maternal behaviour may have been limited in this study by the use of farrowing crates for parturition and the first three days of piglet life. Maternal behaviour is regulated by the release of specific hormones, the functioning of which involves complex mechanisms (Algers & Uvnäs-Moberg 2007) that could be interrupted by behavioural restriction. The prevention of early maternal behavioural expression, particularly nest-building, may have suppressed subsequent maternal behavioural motivation and expression in sows. Several studies have shown that suckling behaviour establishes more easily in litters in which the sow farrowed in pens with straw compared to standard crates (Cronin & Smith 1992). A correlation has also been reported between the expression of nest building behaviour and a reduced incidence of piglet crushing (Andersen, Berg & Bøe 2005; Pedersen et al. 2006). The importance of early maternal behavioural expression on subsequent behaviour requires further research.

The finding that sows in farrowing crates terminated more suckling bouts may indicate a less comfortable environment although this difference did not seem to affect the amount of time piglets spent at the udder, as no difference in bout duration was seen between treatments. It has been shown previously that sows tend to terminate more suckling bouts as piglets mature (Gustafsson et al. 1999) and this effect was seen in both treatments. The finding that sows in farrowing crates terminated more bouts could be another indication of sows' limited ability to communicate with their piglets caused by the physical restriction imposed by crates.

5.3 Piglet welfare

5.3.1 Piglet injuries

The lack of treatment effect observed for piglet skin injuries did not support the hypothesis that fewer injuries would be obtained in farrowing pen housing. A majority of piglet injuries were minor scratches and the pattern of injury suggests most were obtained from fighting among pen-mates. This assumption fits with the finding that frequency of aggression also did not differ between treatments.

5.3.2 Suckling behaviour

The greater amount of sow-piglet interaction occurring around suckling bouts in farrowing pens supported the hypothesis that sows and piglets would interact by close nasal contact more frequently in farrowing pens. Increased interaction benefits piglets by facilitating effective nursing and may also aid piglets through vertical social learning. In a favourable environment, piglets will learn by observation and participation with the sow. For example, piglets can learn to eat solid food from the sow, assisting in the transition to solid feed at weaning (Oostindjer et al. 2011a). Close nasal contact between sows and piglets is thought to be important for recognition and communication and nursing behaviour has been shown to be regulated by pheromones and olfactory cues detected by piglets (Morrow-Tesch & McGlone 1990a; Morrow-Tesch & McGlone 1990b). The decline in frequency of nose-nose contact between sows and piglets around suckling over time was also expected and fits with the parent-offspring conflict theory, in which weaning occurs gradually as the sow invests less in caring for her young (Bøe 1993). Accordingly, suckling bout frequency and duration also decreased over time. The fact that nose contact with sows was more frequent in farrowing pens compared to crates can be explained as follows. Firstly, farrowing pens are less physically restrictive due to greater floor space and lack of crate bars, making the sow's head more accessible to piglets. Secondly, the loose-housing of sows may be more conducive to the expression of maternal behaviour by sows resulting in increased sow initiated close contact with piglets.

Contrary to what was hypothesised however, the number of displacements occurring during suckling and the number of piglets missing suckling bouts were greater in farrowing pens than crates. It is not clear why this may have been the case. The greater floor area in the farrowing pens might have meant that piglets were often sleeping at a greater distance from the sow and did not hear her grunting to initiate suckling. Similarly, the increased area may have allowed for more movement at the udder whereas in the crates, piglets had so little space it was not always possible to change teat position after initiation of suckling/massage.

5.3.3 Piglet behaviour

Significant differences in several parameters of piglet behaviour highlight the relevance of lactation housing to piglet behavioural expression and therefore welfare. The increased play behaviour observed in the farrowing pens was likely a result of a combination of factors. The increased space may have made play behaviour physically more easily expressed. Increased space may have also provided more environmental and social stimulation for piglets, improving their overall welfare and therefore inclination to engage in play behaviour. It was interesting to note that although there was a significant difference in play behaviour between treatments, there was no difference in the frequency of aggression, which appeared to be mostly play-fighting. It is generally accepted that presence of play behavior is a strong indicator of positive welfare and these observed differences supported the hypothesis that increased area and freedom in farrowing pens is associated with increased play behaviour. However, the hypotheses that housing treatment would affect the frequency of nasal contact and aggression between piglets was not supported. The benefits of improved welfare during lactation may well persist beyond weaning. The effect of loose-housing of sows during lactation on piglet play

behaviour seems to continue post weaning, with increased play behaviour expressed by piglets reared in loose-housing systems (Chaloupková et al. 2007; Oostindjer et al. 2011b).

In contrast to the effect the farrowing pen treatment had on play behaviour, manipulative behaviour was reduced and this effect has been reported previously when comparing loose and confined housing of sows. Oostindjer et al. (2011b) observed that lower levels of belly-nosing and other manipulative behaviours were associated with loose-housing of sows. Manipulative-type behaviour is thought to be redirected behaviour, occurring when the appropriate stimulus is inaccessible. Belly-nosing is one common manipulative-type behaviour often seen in early weaned piglets. It is an abnormal behaviour with no obvious function and is sometimes considered a stereotypy. High levels of such behaviour become a problem when skin injury and ulceration result and piglets that express high levels of belly-nosing have also been shown to have a reduced growth rate (Straw & Bartlett 2001). The increased manipulative behaviour observed in crate-housed piglets may indicate a lack of environmental enrichment and/or overcrowding (Dybkjær 1992). Similar to the findings of Oostindjer et al. (2011b), housing treatment did not appear to affect the frequency of nosing pen-mates, mounting or aggression.

Oostindjer et al. (2011a) also demonstrated a process of vertical social learning in which piglets learned to eat solid food from the sow, showing shorter latencies to eat, greater consumption and preference for the feed containing the same added flavour as was consumed by the sow and piglets during lactation. The present experiment failed to show any differences between treatments for investigative and feeding related behaviours in piglets, which did not support the hypotheses that these behaviours would occur more frequently in farrowing pens. However this result makes sense given that the feeding system in the farrowing pens did not allow piglets to actively observe the sow eating or to eat from the same container.

6. Conclusion

In summary, the present experiment provided some evidence of improved welfare for sows and piglets housed in farrowing pens compared to farrowing crates during the lactation period. This was apparent from the increased interaction between sows and piglets and increased frequency of piglet play behavior and the decreased rate of manipulative behavior observed in farrowing pens. These behavioural differences were likely due to a combination of increased social and environmental enrichment provided by the larger space allowance and unrestrained sow in the farrowing pens. In contrast however, the increased sow injuries, displacements at the udder and piglets missing suckling bouts in farrowing pens presents some conflicting evidence with regard to welfare.

Whether the apparent welfare improvements of farrowing pens are significant enough to bring about long-term benefits for piglets and consequently improved sow productivity still requires further research. It would be beneficial to further explore the effect that sow experience has on sow behaviour in farrowing pens, which may confirm greater benefits of the housing system on sow and piglet productivity and welfare. Comparison of productivity measures between the two treatments was inconclusive and also requires further research.

Importantly, comparison of productivity and welfare needs to follow piglets post-weaning, as some of the benefits of lactation housing may not become apparent until later in production.

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