5. Housing of sows during farrowing: a review on pen design, welfare and productivity

L.J. Pedersen, J. Malmkvist and H.M.L. Andersen
Department of Animal Science, Aarhus University, Blichers Allé 20, P.O. Box 50, 8830 Tjele, Denmark; Lene.JuulPedersen@agrsci.dk

Abstract

Housing of sows during farrowing occurs mainly in farrowing crates where the sows are confined between bars without the possibility to turn around. The existing farrowing crates are associated with a number of negative welfare consequences for sows. Furthermore, breeding more piglets in the litter, combined with the fact that sows have generally become both longer and wider over the past 15 years, means that the size of the current crates is not large enough neither to accommodate the sow nor piglets until 4 weeks after birth. Therefore, alternatives to the current farrowing crate are necessary. Pens for loose housed sows are good alternatives for the sake of sow welfare. Review of the existing literature does not suggest that loose housing is associated with higher general piglet mortality than housing in farrowing crates. Knowledge from studies on behavioural needs of sow and piglet during farrowing and lactation is reviewed and used to make general recommendations on pen design. From this knowledge, prototypes of farrowing pens have been developed and are currently tested in smaller scale in production herds. Through this, more experience is being gathered on the pens' function in practice that contribute to having the first prototypes adapted and further developed so that they become an attractive alternative to the farrowing crate for the farmer both economically and with regard to animal welfare.

Keywords: farrowing crates, loose-housing, piglet mortality, behaviour, stress, thermoregulation

5.1 Background

In the 1960s to 1970s, the farrowing crate became a fast growing sow housing method worldwide. First of all, the farrowing crate saved space and allowed easy manure handling through slatted flooring behind the sow. Based on production experiments in commercial herds, the farrowing crate seemed not to increase mortality rate and was thus found economically competitive with the traditional pen system in Denmark (Pedersen and Ingvartsen, 1981) and other countries (Gustafsson, 1983). Currently, the majority of sows in the EU are housed in crates during farrowing and lactation (EFSA, 2007).The farrowing crate consists of a pen within which bars have been set up to prevent the sow from turning around. Outside the bars there is a separate space for the piglets and in some systems a roof covered creep area is situated in a corner of the pen. Usually, the creep area is installed with either floor heating and/or radiant heating from an infra-red lamp. There is no international survey on the size and design of currently used farrowing crates. A Danish survey reported by Pedersen *et al.* (2010) measured the size and design of farrowing crates in 84 Danish herds. The median size of the farrowing crates was 3.95 m^2 (25-75% quartile: 3.75-4.25 m^2). The median length of the bars crating the sows measured from the rear end of the through was 198 cm (25-75% quartile: 190-200 cm), while the median width at the front part of

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the sow was 57 cm (25-75% quartile: 55-60 cm) while the median width at the rear end of the sow was 64 cm (25-75% quartile: 58-70 cm). The pens had either fully slatted floor (11 out of 84) or partly slatted floor. Straw or saw dust was given in some herds to the piglets usually out of reach of the sow (21 herds out of 84 herds gave chopped straw or saw dust to the piglets).

Due to current public concern about animal welfare there is, however, a growing pressure on the pig industry to change the crate system to a pen system where sows are kept loose. However, at the moment, Sweden, Norway, and Switzerland are the only countries where the farrowing crate is banned. The pig industry is concerned about increased piglet mortality and increased cost due to space and labour if the crate system will be banned. Therefore, many countries have encouraged and initiated research on farrowing systems for loose housed sows.

In the present review, the welfare consequences of crating the sows are considered and current knowledge of design and productivity in farrowing pens for loose housed sows is reviewed.

5.2 Welfare consequences of the farrowing crate

When kept under free range conditions, sows will isolate themselves from the rest of the herd a few days prior to farrowing and choose a sheltered location where they can build a nest. Nest building consists of several phases. First, the sow makes an indentation in the ground, then it collects and organizes the nesting material and finally, a few hours before farrowing, the sow will go into the nest where she lies quietly until the piglets are born (Jensen, 1986; Jensen *et al.*, 1993; Stolba and Wood-Gush, 1989). From approx. 24 h before farrowing endogen stimuli motivates the sow highly for nest building and sows will nest build intensively until a few hours before farrowing (Wischer *et al.*, 2009a).

If the sows, however, are crated the ability to demonstrate actual nesting behaviour is very limited and is seen primarily as increased restlessness and redirected nesting activity against the equipment (Damm *et al.*, 2003; Hartsock and Barczewski, 1997; Jarvis *et al.*, 1997, 2001 Weber and Troxler, 1988) or as oral/nasal stereotypies (Weber, 1984; Damm *et al.*, 2003). They have also no control over selection of a nest site, which contains the qualities preferred by sows in terms of for example isolation (Jensen, 1986; Stolba and Woodgush, 1984). Lactating sows will leave the nest site for dunging (Andersen and Pedersen, 2011; Damm and Pedersen, 2000; Pajor *et al.*, 2000; Schmid, 1992) while crated sows are forced to dung at the nest site. Besides, crating even has a negative effect on sows' possibility to thermoregulate. Sows have an increased preference for lying on a cool surface (Phillips *et al.*, 2000) concurrently with their heat production being increased by increasing feed intake and milk yield as the lactation proceeds. Crated sows are thus susceptible to heat stress as they have limited possibilities to thermoregulate (Prunier *et al.*, 1997; Quiniou and Noblet, 1999).

Crating during the gestation period has been shown to affect strength of muscles (Marchant and Broom, 1996) and reduce cardiovascular fitness (Marchant *et al.*, 1997) and bone strength (Marchant and Broom, 1996). Crating during farrowing and lactation most likely will have similar effects. However, the effects may be less extensive due to the shorter period of confinement. Negative effects of crating on lesions of hoof and leg and on the maintenance of muscle mass

are often reported as a consequence of the lack of movement over time (Barnett *et al.*, 2001). Leeb *et al.* (2001) have suggested that the inability to move around is the cause of the increased incidence of thickening of the skin (callosities) seen in crated sows. In addition to the physical consequences of crating during farrowing and lactation, also stress responses such as increased heart rate (Damm *et al.*, 2003) and increased plasma concentration of the stress hormone cortisol are seen in crated sows compared to loose housed sows before (Jarvis *et al.*, 1997; Lawrence *et al.*, 1994); and after farrowing (Oliviero *et al.*, 2008). During lactation Jarvis *et al.* (2006) found that plasma levels of cortisol after a CRH injection (a hormone that via ACTH stimulates adrenal secretion of cortisol) on day 29 of lactation were higher in the crated sows than in the loose housed sows, indicating that also persistent crating has negative effects on sow welfare.

From the year 2013, all sows in the EU must be kept loose in groups throughout gestation. This probably means that the long term negative effects of crating will be reduced (such as reduced muscle and bone strength) whereas the more immediate stress response to crating will be increased each time the sows are moved to the farrowing crate (Boyle *et al.*, 2000). The latter may result in prolonged birth (Oliviero *et al.*, 2008, 2010) and increased risk of still birth particularly in young gilts that are confined for the first time (Cronin *et al.*, 1996; Pedersen and Jensen, 2008).

5.3 Space for sow and piglets in farrowing crates

Crated sows will often bump against the equipment when they get up and lie down (Troxler and Weber, 1989; Harris and Gonyou, 1998) indicating disrupted getting up and lying down behaviour. In a Danish survey on 10 farms with crated sows, it was found by examination of 550 sows, that 41% showed deviating lying-down behaviour that was often associated with lameness (Bonde *et al.*, 2004). A similar study has not been carried out on penned sows. Taylor *et al.*(1988), however, reported that crated gilts compared with loose housed gilts rose fewer times, lay more down for longer periods, and changed posture more frequently when lying down. Anil *et al.*(2002) described that the available space within bars affected sows' getting up and lying down behaviour. Large sows took longer time to lie down and were lying down longer time than small sows when space was identical.

According to the EU directive 2001/93/EC 'pens must be designed so that each pig can lie down as well as rest and get up without difficulty'. Measurements of both the dynamic and static space used by sows, indicate that to allow undisturbed getting up, lying down and resting, space between the bars must be at least 220 cm in length and 80-90 cm in width (Baxter and Schwaller, 1983; Curtis *et al.*, 1989; McGlone *et al.*, 2004; Moustsen *et al.*, 2004).

Moustsen *et al.* (2004) measured the physical dimension of 368 Danish cross bred sows. Since the dimension of the equipment should be able to accommodate all sows the 95% quartile should be considered and was measured to be 202 cm in length, 47 cm in shoulder width and 71 cm in depth. The dynamic space used for getting up and lying down was measured to be approximately 32 cm in width and 16 cm in length in addition to the sows' own dimensions (Moustsen and Duus, 2006). When this is compared to the dimension of the farrowing crates (in average approximately 198×60 cm, see background section for details) space in conventional crates is both too narrow

in length and width in order for the sows to perform an undisturbed getting up and lying down movement.

Piglets may also be subjected to some space problems due to the dimensions of the farrowing pen (Figure 5.1). The EU directive 2001/93/EC states that 'if a farrowing crate is used, piglets must have sufficient space to suck without difficulty'. To accommodate this for 95% of (Danish) sows in all situations, pens must be at least 202 cm wide: 90 cm between the bars and 56 cm to both sides. The 56 cm is what an average piglet was measured to be in length at week 4 of age (Moustsen and Poulsen, 2004a). The length of the pens should be at least 280 cm long: 220 cm to accommodate 95% of (the Danish) sows including dynamic space for movements, 30 cm in front to the through and at least 30 cm (length of an underarm) to facilitate farrowing assistance (see Figure 5.2). In addition, part of the flooring should also according to the EU directive be 'large enough for all piglets to rest on it at the same time, must be solid floor or covered with a mat or straw or other suitable material'. This would, according to measurements (Moustsen and Poulsen, 2004b) of 4 weeks old piglets in semi-lateral laying, require that at least 1.1 m^2 was solid or covered by straw or mats to accommodate 10 piglets, a common litter size at weaning.

If the above conditions in the EU directive must be fulfilled in the farrowing crate, its measures must therefore be at least 5.6 m^2 (200 cm width × 280 cm length) based on the above arguments. Of this area, at least 1.1 m^2 must be solid floor, separated from the sow, where the piglets can rest. Sow space must make up approx. 2 m^2 (90×220 cm) of the total area (Figure 5.2).

Figure 5.1. Photo of a common farrowing crate with space restriction. The picture illustrates problems with limited space for the piglets to suckle. The piglets at the picture are almost new-born. In addition, the space in length is too small resulting in the sow resting its head on the trough due to limited space in the length of the crate.

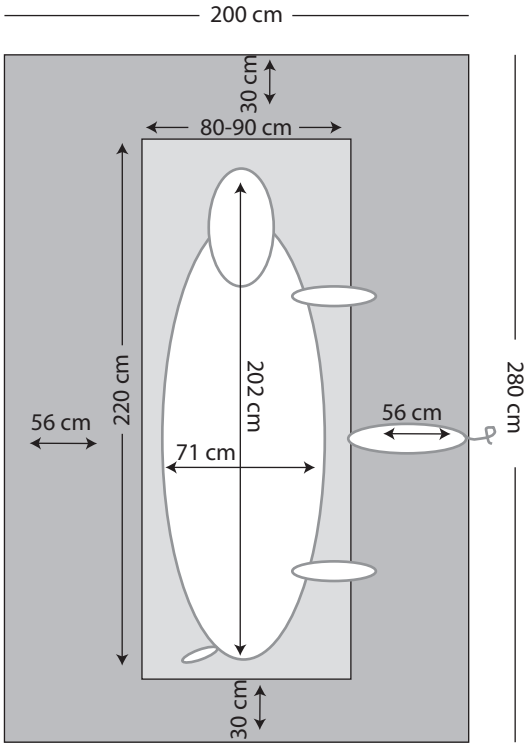

Figure 5.2. Schematic drawing of the estimated dimensions of farrowing crates that allow enough space for physical dimension of sow and piglets as well as for dynamic movements for getting up and lying down. The measures are based upon the 95% quartile of the physical dimensions and space used for movements of Danish cross bred production sows and the 95% quartile of length of piglets at 4 weeks of age.

Practical experiences, however, suggest that this much space between the farrowing bars can result in small sows turning around in the crate, which will result in malfunctioning of the crate. Therefore, it may be necessary to consider different sized crates for small and large sows.

5.4 Piglet mortality in relation to housing

5.4.1 Overall mortality

Despite the fact that the crate system has been considered to reduce piglet mortality mainly through a reduction of crushing, there is not much scientific evidence for this when considering the few large surveys that compare the mortality rate in commercial herds. An older Swedish herd study (Gustafsson, 1983) showed no difference in piglet mortality between crated and loose sows (crated 18.74%, n=15,607 vs. loose 18.75%, n=56,900 litters). Similar results were found in Danish herds around the same period (Pedersen and Ingwersen, 1981), with no differences between loose and crated sows either (crated sows in pens with fully drained floor 10.2%, n=1,085

vs. loose sows 10.5%, n=697). Bäckström *et al.* (1994), however, found a slightly higher piglet mortality in litters with crated sows compared to litters with loose housed sows (crated 18.7%, n=765 vs. loose 16.9%, n=3,219). In a more recent Danish study (Moustsen and Poulsen, 2004b), the number of weaned piglets was compared in one herd, consisting of both crated and loose sows. There was no difference in the number of weaned piglets (average of 10.4 piglets per litter) between the two pen systems (crates n=288 and loose n=284, respectively). O'Reilly *et al.* (2006) examined risk factors associated with high piglet mortality in 67 herds in England and Wales. Piglet mortality was not different between herds with crated sows and loose sows whether indoor or outdoor. The average mortality was 10.7% of live births. However, there were only few herds with indoor loose sows. In a large survey from commercial herds in Switzerland, the production data from 482 herds with crated sows was compared with data from 173 herds with loose sows (total 44,837 farrowings) (Weber *et al.*, 2007). There was no difference between herds with crated and loose sows in the number of piglets that died after farrowing (crates 1.42 per litter vs. loose 1.40 per litter; average number of live born piglets: 11.0, average number of stillborn piglets: 0.6). A recent cohort study (KilBride *et al.*, 2012) on commercial pig farms in UK confirmed the results of the study in Switzerland. They also found no difference between farms with crated sows (n=49 farms) and farms with penned sows (n=15 farms) either in the percentage of live born mortality (crates 11.7% vs. loose 10.9%) or in the percentage of stillborn piglets (crates 7.2% vs. loose 8.3%).

5.4.2 Significance of litter size on piglet mortality

Many studies have shown that the proportion of dead piglets is increasing with increasing litter size both in pens and crates (Pedersen *et al.*, 2006; Roehe and Kalm, 2000; Su *et al.*, 2007; Weber *et al.*, 2007). Whether the influence of litter size is stronger in pens than in crates or *vice versa* has to our knowledge not been analysed.

5.4.3 Causes of piglet mortality

Stillborn piglets

The birth is one of the biggest challenges for the yet unborn piglets as the proportion of stillborn piglets is the largest source to losses in sow production. In herd studies, still birth is often reported to be around 5-11% of total born piglets (KilBride *et al.*, 2012; Su *et al.* 2007; Weber *et al.*, 2007). KilBride *et al.* (2012) found no difference in risk of still birth between indoor housed crated sows and loose sows. However, the risk of still birth was lower in outdoor housed sows compared to indoor housed sows. In indoor housed sows, both Cronin *et al.*(1996) and Gustaffson (1983) found increased risk of still birth in gilts crated for the first time compared to penned gilts. Also Pedersen and Jensen (2008) found more still births in crated gilts compared to loose gilts. However, in their study, all gilts were introduced to the farrowing house close to the time of farrowing. Stillborn piglets are more likely to be born after long birth intervals and may thus have suffered from anoxia during birth (Pedersen *et al.*, 2006). Prolonged stays in the birth canal is not only a risk to stillborn piglets but do also increase the live born piglets' risk of dying from other causes (e.g. illness, poor growth, etc.) (Pedersen *et al.*, 2006). Confinement in farrowing crates has been shown to induce physiological stress responses in sows that may affect the progress of farrowing through inhibition of oxytocin (Jarvis *et al.*, 1997; Lawrence *et al.*, 1992, 1994;

Oliviero *et al.*, 2008). Such mechanism may explain the prolonged birth intervals (Biensen *et al.*, 1996; Oliviero *et al.*, 2008, 2010; Pedersen and Jensen, 2008; Wülbers-Mindermann *et al.*, 2002) and increased number of stillborn piglets occurring in crated sows compared to loose sows; particularly in young gilts that are confined for the first time (Cronin *et al.*, 1996; Gustafsson, 1983; Pedersen and Jensen, 2008).

Savaging by the sow at birth

Savaging is observed both in gilts and older sows and is considered an abnormal behaviour characterized by general agitation during birth (Ahlstrom *et al.*, 2002; Chen *et al.*, 2008) but tend to be more common in gilts than in older sows (Chen *et al.*, 2008; Harris and Gonyou, 2003; Marchant Forde, 2002). While Jarvis *et al.* (2004) found increased savaging in crated sows compared to loose housed sows, Pedersen *et al.* (2011) found no difference between the systems, while Marchant Forde (2002) found more savaging in pens compared to crates. No comparison between crates and pens has been performed with a large sample size and the results are non-conclusive.

Crushing

Crushing is the second largest contribution to mortality both in farrowing crates and loose house pens. However, it is difficult to evaluate if crushing is the primary cause of death since weak and hypothermic piglets will be more susceptible to crushing since they do not respond towards the sow's movements. In addition, in loose housed sows it is likely that sows lie on already dead piglets and that these are also mistakenly categorized as crushed. Pedersen *et al.* (2011) found in a controlled experimental study of dead piglets from 104 gilts (crated sows n=55, loose sows n=50) that 5.4% of the total number of born piglets died as a result of crushing. This categorization was based on a combination of autopsy and verification of the death on video. In the previously mentioned farm survey from Switzerland by Weber *et al.* (2007), less piglets were categorized by the farmer as dead due to crushing in the crate compared to the loose house pens (0.52 vs. 0.62 piglets per litter), while more piglets from crated sows were categorized as dead due to other causes (0.89 vs. 0.78 piglets per litter). Similar results were found by KilBride *et al.* (2012), who reported lower incidence of crushing in crates compared to loose house systems (crates 4.6% vs. loose 6.0%). In contrast, more piglets died from other causes in crates (crates 6.7% vs. loose 4.4%). In another farm study of 146 sows (Cronin *et al.*, 2000), the farmer categorized a smaller proportion of the dead piglets as crushed by the sows in the crates compared to pens (crates 20% vs. loose 45%, P=0.06) while a larger proportion were categorized as dead due to being categorized as weak and small (crates 24% vs. loose 14%, P=0.08). Thus it seems uncertain that the difference in causes of death found in herd surveys is due to a genuine difference between crates and pens. The recorded difference may be related both to the farmer's subjective observations of death causes in the two systems or to the fact that a loose sow is more likely to lie down on weak or already dead piglets than is the case for a crated sow.

Hypothermia and starvation

Apart from stillborn piglets and crushed piglets, piglets are dying from hypothermia and starvation. However, it is difficult to distinguish the triggering cause of death when it comes to piglets that have died due to crushing, hypothermia and starvation as starvation and hypothermia often precede crushing. Hypothermia 2 hours after birth was thus a significant risk factor for piglets to be recorded as dying from crushing, starvation, and diseases both in crates and indoor pens (Pedersen *et al.*, 2011; Tuchscherer *et al.*, 2000), as well as in outdoor systems (Baxter *et al.*, 2009).

Diseases

It is difficult to specify how many piglets die from diseases because it depends on the individual herd's health status and the current infection risk. There are no studies indicating a different risk of death due to diseases between crates and pens.

5.5 Design of farrowing pens for loose housed sows

5.5.1 Prevention of crushing

Most crushing in loose house pens occurs in connection with the sows lying down without support of the walls. Marchant *et al.* (2001) reported that the risk of a piglet to be squeezed to death when the loose sow lie down in a pen was only 0.5% when the sow lie down against a wall, whereas it was 14% when the sow lie down without support from a wall. The wall may support the lying down movement to be more slow and controlled. A pen design which ensures that the sows use support wherever possible when lying down can, therefore, be expected to reduce piglet mortality. Loose house pens are typically designed with a rail on all walls to prevent the sow from squeezing the piglets against the wall when she lies down. However, Damm *et al.*(2006) showed that sows preferred to lie against a rail-free wall compared to a wall equipped with a farrowing rail at the bottom of the wall. In their study, sows did not differentiate between using sloping walls vs. straight walls, or between ribbed vs. plain walls for supporting lying behaviour. Thus a sow is more attracted to use support when the walls are free from farrowing rails. In order still to maintain an escape zone for the piglets there should be both an outer and an inner wall. In that way piglets avoid being crushed against the wall, which further benefits survival (Figure 5.3).

It is difficult, though, to completely avoid that sows lie down without support. Therefore, reducing the risky behaviour in these situations also should be considered through the stimulation of maternal behaviour. Sows are strongly motivated for nest-building. The nesting behaviour is considered to be influenced both by internal and external stimuli and is important for maternal behaviour after birth (see review by Wischner *et al.*, 2009a). It has generally been found that high activity during nesting (Andersen *et al.*, 2005; Pedersen *et al.*, 2006; Wischner *et al.*, 2009b) and low activity during parturition (Thodberg *et al.*, 2008) are associated with a reduced risk of crushing. Access to straw can stimulate nesting activity (Thodberg *et al.*, 1999). Damm *et al.* (2010) showed that the number of crushing situations was reduced in sows with free access to straw. Herskin *et al.*(1998) found that sows during parturition were calmer when having access

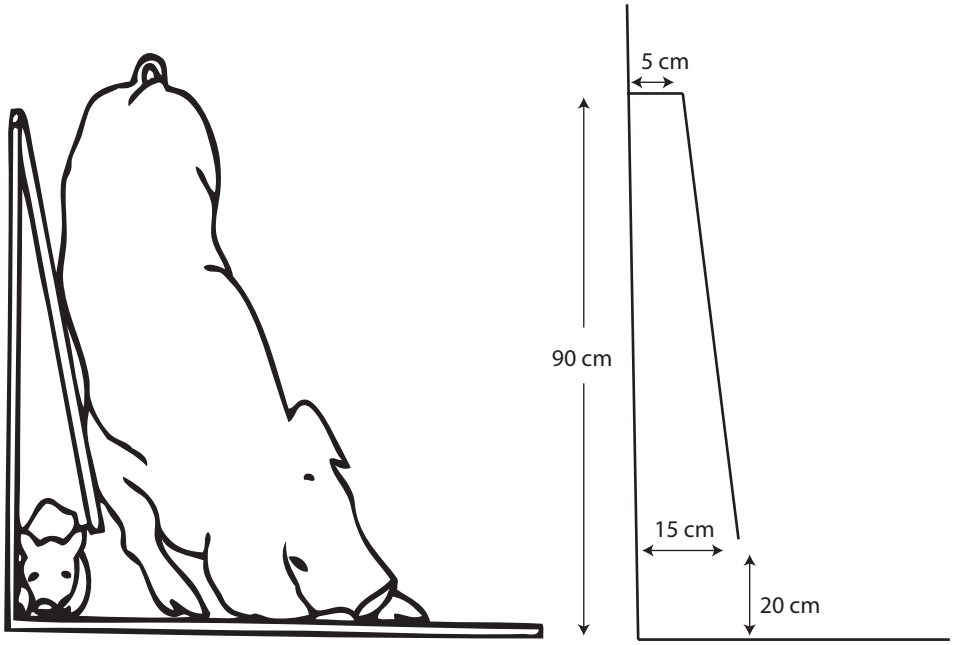

Figure 5.3. Sloping walls with escape zones for piglets. The walls attract the sow to use support during lying down. The double wall protects the piglets from being crushed against the wall. To the right, the dimension of the walls and escape zone is given by Moustsen (2006).

to straw and Pedersen *et al.* (2003) reported that feedback from a nest resulted in the new-born piglets being quicker to find teats and thus gaining earlier access to colostrum. Other types of nesting materials may have the same effects, but have not been investigated to the same extent as straw. For example, Damm *et al.* (2000) found that nesting behaviour was terminated sooner before birth with access to braches than without. Burri *et al.* (2009) have compared whole straw with chopped straw for nesting. They found significantly more nesting activity directed towards the equipment (indicative of redirected behaviour) when chopped straw was provided compared to whole straw. Furthermore, there were significantly more dangerous situations on day 1 after farrowing in litters where the sow had access to chopped straw compared to whole straw. On this background, we conclude that access to adequate straw can improve maternal behaviour of importance for piglet crushing in loose housed sows. The sows' use of straw was estimated based upon the daily removal of straw (unpublished data) from straw rack in pens of 69 sows involved in three experiments (Damm *et al.*, 2010; Pedersen and Jensen, 2008; Pedersen *et al.*, 2007a). In average the sows removed approx. 0.5 kg of whole straw daily before and after farrowing. On the nesting day, however, the sows used an average of approx. 1.5 kg of whole straw with a variation from less than 0.5 kg and up to 7.5 kg.

5.5.2 Space for sow and piglets

To avoid crushing and optimize the piglets' milk intake, it is necessary with sufficient space in the farrowing pen for the sow to lie down easily, for the piglets to suckle without being hindered by the equipment and for all piglets to rest in the heated piglet area simultaneously. For example, Cronin *et al.* (1998) found that smaller and narrow compared to larger and wider nest sites induced more restless postural chances in sows and reduced the time piglets spent at the udder during nursing. As for the crate system, the physical dimension of sow and piglets is important to incorporate in the pen design together with the dynamic space used for getting up and lying down.

5.5.3 Thermal comfort of sow and new-born piglets

Significant challenges are connected to designing the farrowing environment so that both the sow's and piglets' thermal needs are met as the sows' upper critical thermal limit has been reported to be at 22 °C, whereas the new-born piglets' zone of comfort is above 34 °C. In traditional farrowing crates, piglets' thermal need has been considered, partly by keeping the room temperature relatively high (around 20-22 °C) and partly by providing additional heat in a separate piglet corner. A number of studies have shown that new-born piglets do not use such a heated corner extensively until 2-3 days after initiation of parturition (Hrupka *et al.*, 2000a,b). At this later point in time, however, the piglets are less prone to hypothermia. Malmkvist *et al.* (2006) showed that the additional floor heating (35 °C) from approx. 10 h after the start of nest building to 2 days after start of farrowing increased the piglets' ability to maintain normal body temperature just after birth, it reduced time to first colostrum intake and increased the piglets' chance of survival. Piglets with floor heating at the birth site until 48 h after birth of first piglet used the heated piglet corner later and to a lesser extent than piglets that only had heat in this area of the pen (Houbak *et al.*, 2006). In spite of this, the piglet's chances of survival increased significantly in pens with floor heating (with heat 8.7% dead of live born, without heating 15.8% dead of live born). A recent study has shown that the duration of the floor heating can be reduced from 48 h to 12 h without negative effects on the piglets' body temperature at 24 h or 48 h after birth (Pedersen *et al.*, 2013). Even with floor heating in the pens, the room temperature is of great importance for the development in piglets' body temperature. Piglets born at 25 °C vs. 15 °C and 20 °C had only a slight drop in body temperature after birth and a rapid increase to 37 °C. Even at 24 h and 48 h after birth, piglets' rectal temperature was still higher at a room temperature of 25 °C and 20 °C than of 15 °C (Pedersen *et al.*, 2013). After the early postnatal period, the piglets' use of the creep was significantly higher at low than at high room temperatures. When the room temperature was 15 °C and to a lesser extent when it was 20 °C the use of the creep also increased within 6 h after turning off the floor heat. However, the percentage of piglets that used the creep area was still below 20% during the first 24 h after birth of first piglet even at the cold room temperature and without floor heating. Taken together, these results indicate that a heated creep (1) may have an important thermoregulatory function for the piglets, being dependent on the outer temperature, but (2) is not sufficient to accommodate the heat requirements of all piglets, especially during the early postnatal period, during which the risk of hypothermia and dying is increased.

Provision of floor heating in pens makes the question of whether sows are exposed to heat stress important. Malmkvist *et al.* (2009) found increased plasma concentration of stress hormones in sows housed in pens with floor heating in the entire pen. This was, however, not to such an extent that it affected the sows' immune response (Damgaard *et al.*, 2009), farrowing course or blood concentrations of oxytocin (Malmkvist *et al.*, 2009). Using only partly heated floor in a recent study showed that sows had an increased respiratory rate, body temperature and surface temperature with increasing room temperatures combined with floor heating. The sows used the unheated slatted floor to cool, but without affecting the choice of farrowing site, which primarily took place on the solid – and heated (35 °C) – floor (Malmkvist *et al.*, 2012). Overall, there was an equal high feed intake during the first 21 d of lactation at the high and low temperatures. There was no weight loss of the sows at any of the three room temperatures, suggesting that loose housed sows were able to adapt to the higher room temperatures (25 °C) throughout the lactation (Malmkvist *et al.*, 2012). The relative high feed intake in loose housed sows during warm room temperatures contrasts results previously reported in crated sows, from which reduced feed intake and lactation weight loss typically are reported following room temperatures above 22 °C during lactation (Prunier *et al.*, 1997; Quiniou and Noblet, 1999).

In addition, Pedersen *et al.* (2007b) and Phillips *et al.*(2000) showed that sows during the first 2 to 3 days after farrowing preferred to lie on a heated floor over an unheated floor, even at high room temperature (Malmkvist *et al.* 2012). These results indicate that partly floor heating will not result in sows giving birth to piglets at the slatted floor area and is therefore a possible option to improve the thermal environments at the birth place of loose housed sows and at the same time improve thermal comfort and viability of the new-born piglets.

Zone division of the farrowing pen

In order to obtain a good hygiene in a farrowing pen it is essential that the sows are able to divide the pen into zones of resting/farrowing and of dunging. The dunging area can then be built with slatted floor to assure easy manure handling. When given the opportunity, sows clearly zoned a farrowing pen (Damm and Pedersen, 2000; Damm *et al.*, 2010) into a nesting area and a dunging area. An attractive 'lie down' wall can additionally motivate the sow to lie down in a certain part of the pen (Damm *et al.*, 2006). This part of the pen should include good conditions for the piglets, as for example a heated solid floor during farrowing as mentioned above and/or straw. Likewise, even though slatted floor is used for lying during periods with high temperatures, the sows still successfully divide the pen into zones for farrowing and nursing (solid floor) vs. zones for thermoregulation and elimination (slatted floor) (Malmkvist *et al.* 2012). Another way to attract the sow to a specific area of the pen could be to create some kind of isolation from neighbouring sows, as sows prefer to farrow in a visual enclosed area for example by solid walls to neighbouring pens (Hunt and Petchey, 1989). Other types of screening or covering may also attract the sow to a specific farrowing site, e.g. a roof covered pen (Phillips *et al.*, 1991; Sancha and Arey, 1995); even though Damm *et al.*(2010) did not demonstrate any preference of sows to farrow under a non-solid roof cover, maybe due to factors such as position in height and/or texture. Another element controlling the sow's choice of resting and dunging area is the location of the feeders. Sows prefer to dung away from the feeders and will go as far away from the feeder as possible placing themselves with their head turned away from the feeder (Andersen and Pedersen, 2011).

The study showed that the sows were dunging with their head turned away from the resting area and away from feeders in 75% of all dunging events.

5.6 Design of farrowing pens for loose housed sows

Based on the knowledge about sows' behaviour, physiological responses and preferences during farrowing and knowledge about what triggers risky situations for neonatal piglet mortality, it is possible to specify recommendations for the design of farrowing pens for loose housed sows, taking both improved animal welfare and high productivity into consideration. We recommend that, in order to meet the needs of sows and piglets, farrowing and lactation housing are designed according to the following principles:

- Loose housing of sows during the entire reproductive cycle as this reduces stress during parturition thereby increasing the chance of easy delivery with fewer stillborn piglets.
- Provision of additional heat sources for the new-born piglets such as floor heating at the birth site and/or increased room temperature around farrowing up to 25 °C, present at the time of birth of first piglet in the litter. This heat supply has largest positive impact on piglet vitality during the first 12 h of life.
- Establishment of a closed area in the pen with solid floor and solid walls (or other means) to reduce disturbances from neighbours. This creates the possibility for the sow to select an undisturbed area for nesting and resting, and thus optimizing the chances that piglets are born on the thermal favourable solid floor.
- Provision of more than 1 to 2 kg of straw or other nesting material prior to the nest building period to meet the sows' motivation to nest build and further enhance a zone division, improve the thermal climate and help the piglets to dry after farrowing.
- Establishment of walls free from traditional farrowing rails, but with build-in piglet escape zones, in the nesting area to increase zone division and to support sows lying down. In case of limited space in the pen, it may be advantageous to let the inner walls slope inwards in the pen (Figure 5.3). This will result in walls taking up less space at the heights of a standing sow compared to the floor level of the lying sow, and will thus allow more space for the sow when moving around in standing position.
- Establishment of an area with slatted floor and open equipment to the neighbouring pen, in order to make it easier for the sow to zone divide the pen as it prefers to use the enclosed area for resting with piglets and to dung away from this area in the open area with slatted floor. The slatted floor area may also be used for cooling down when room temperatures are high. The slatted floor area should measure no less than a sow's length and no less than 1 m on the short side in order for the sow to be able to turn away from the feed trough during dunging. Thus the manure lands on the slatted floor. In herds with many large sows more space is needed to avoid the faeces to land in the feed through.
- Placement of feeders and water should be located at the slatted floor. Hereby activity in the nesting area is reduced. Since sows dung away from the feed and away from the nest it is possible to control that the majority of the faeces and urine is positioned on the slatted floor.
- To further improve hygiene and save labour cost for pen cleaning, extra drainage at the floor around the dunging area can be made and/or a small iron rail can be set up to further help

partitioning the slatted floor area from the concrete floor area and thus preventing the sow from standing diagonally on the slatted floor (Figure 5.4A).
- Establishment of a creep area of at least 1.1 m^2 for the piglets with additional heating turned on after the heating device at the birth site is turned off.

In addition to these recommendations, we generally recommend that the pen is positioned in the room in a way that allows easy overview and access to the piglets. This can for example be achieved by turning the pen so the creep area is facing towards the passage where the entrance to the pen is located. The piglets can now be reached from the passage and unnecessary disturbances of the sows are avoided. In cases where sows need treatments or in cases of aggressive sows we

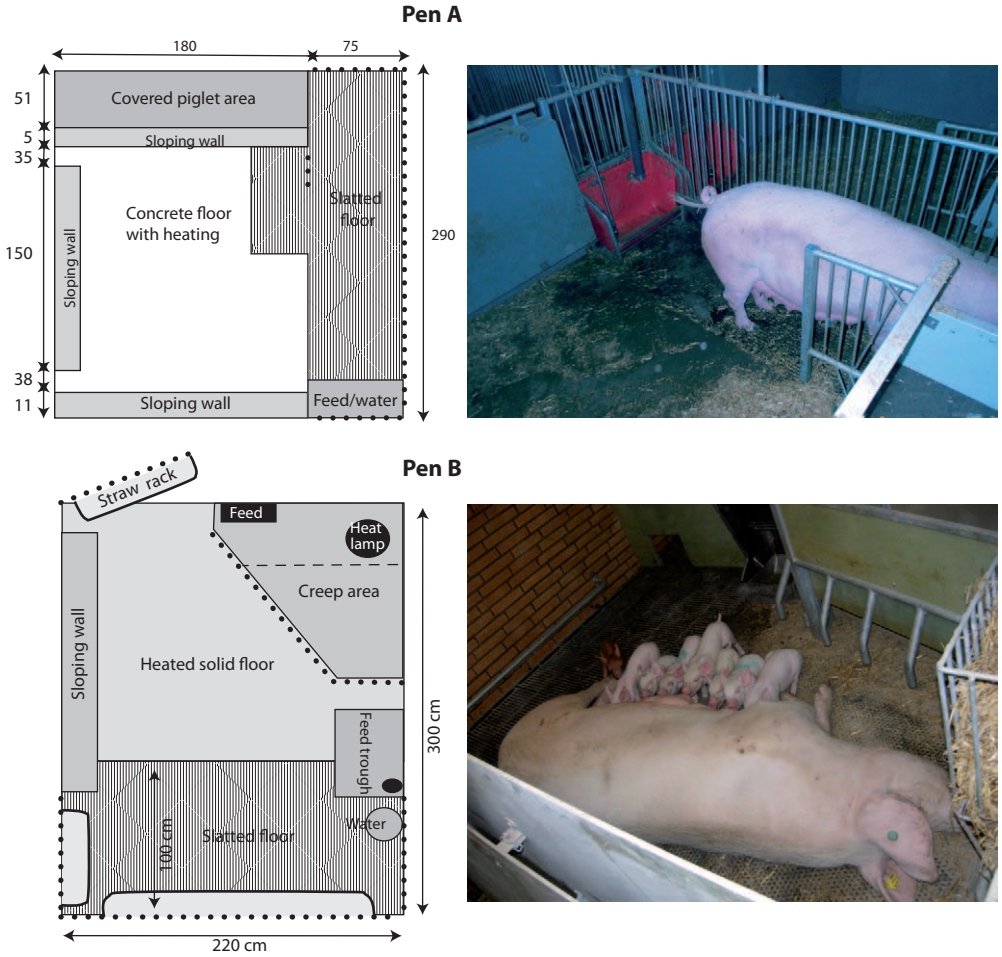

Figure 5.4. Example of pens for loose housed sows designed according to some of the major recommendations in this paper. Pen A measures 7.4 m^2. The photo of Pen A shows the small rail preventing the rear end of the sow to be above the solid floor during dunging. Pen B measures 6.6 m^2.

recommend that a device is established that can confine the sow during handling. Examples of pens designed after the above principles are shown in Figure 5.4. Such pens are currently tested in smaller scale in Danish production herds. More experience on the pens' function in practice will be gathered and can contribute to the first prototypes being adapted and further developed so that they become an attractive alternative to the farrowing crate for the farmer both economically and with regard to animal welfare.

5.7 Conclusion

Today, there is abundant knowledge indicating that the traditional farrowing crate has negative impact on sow welfare. At the same time, the majority of the large-scale studies do not indicate that crating significantly reduces piglet mortality compared to well-designed loose house pens. In recent years, much knowledge has been generated, which can be used to design farrowing pens for loose housed sows both respecting piglets, sows and farmer needs. Therefore, there is good opportunity to design farrowing pens for loose housed sows, having the potential to be a competitive alternative to the existing farrowing crate.

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