Why should we worry about farrowing systems for sows: insights from studies on maternal behavior?

Inger Lise Andersen & Marko Ocepek

Department of Animal and Aquacultural Sciences,
Faculty of Bioscience, Norwegain University of Life sciences, Norway.
*Corresponding author: inger-lise.andersen@nmbu.no

Maternal investment, sow behavioural needs and criteria for housing design

The reproductive strategy of producing large broods and smaller young, resulting in a higher mortality rate, fits the picture of domestic pigs remarkably well (reviewed by Drake et al. 2008). The average litter size in domestic sows is around 12 to 14 piglets, but litters of above 20 piglets are not uncommon even in gilts, although the number of functional teats is usually between 14 and 16 (e.g. Vasdal & Andersen, 2011; Ocepek et al., 2016). This is due to a high selection pressure for increased number of liveborn piglets. However, a high litter investment (i.e. litter weight at weaning plus weight of stillborn piglets), is associated with a higher weight loss during lactation and a higher prevalence of shoulder lesions, especially in primiparous sows that still need resources for their own growth and development (Ocepek et al., 2016). Thus, breeding for an increased maternal investment at a young age is accompanied with substantial costs for the sows, with potential negative consequences for the residual reproductive value and longevity. There is a strong neonatal competition for teats even when the number of functional teats equals the number of offspring as some piglets may in fact monopolize two teats shortly after birth (Andersen et al., 2011; Ocepek et al., 2017a). During this competition, some piglets will not get access to a teat during milk let-down, will give up fighting after several unsuccessful attempts, and within 2 or 3 days, they will starve to death (e.g. Andersen et al., 2011). Piglet mortality caused by maternal crushing of piglets, many of which has no teat success, and starvation caused by sibling competition, increases with increasing litter size for most sow parities (e.g. Andersen et al., 2011; Ocepec et al., 2017a). A relatively constant number of surviving piglets at the time of weaning, therefore, suggests that 10 to 12 piglets could be close to the upper limit that the domestic sow can take care of without human assistance. However, some pig breeding companies claim that this biological threshold can be stretched even further and are not willing to reduce the weight on number of liveborn piglets in the breeding goal. Other negative consequences of larger litters are that a higher proportion of nursings is terminated before milk let-down ("unsuccessful" nursing), that nursing interval increases (fewer nursings per day), resulting in more variation in piglet weight and thus quality of the young at weaning (Ocepek et al., 2017a). Our results suggest that further artificial selection for larger litters in maternal lines is not sustainable because it compromises sow and piglet welfare and fitness. Larger litters are also more labor requireing for the farmer at the time of farrowing.

Because the sows have become larger, heavier and longer, the udder has become larger and the teat pair distance has increased especially in middle and posterior teats (Ocepek et al., 2016). As a result of this, more than 20% of the teats are inaccessible for the new born piglets at the time of

birth (Ocepek et al., 2016), either because they are hidden towards the floor or because they are placed too high and out of reach (Vasdal & Andersen, 2011). Furthermore, this problem increases with increasing sow parity. Teat and udder quality traits are therefore extremely important and needs to be addressed with a simple and efficient methodology, for instance by using the tools of digital picture analysis targeting the part of the udder that is most problematic regarding teat pair distance and accessibility for the piglets.

Some behavioural traits important for piglet survival and litter weight, documented both experimentally with pure breeds and on crossbreds with 895 sows from 45 different commercial farms (Ocepek & Andersen, 2017; Ocepek et al., 2017b; Ocepek et al., 2018), are nestbuilding activity, sow-initiated communication with piglets and sow carefulness while being active in the pen. High levels of sow-initiated communication (i.e. sniff, grunt, nudge, push) while resting outside the time of nursing, on the other hand, may indicate restless, nervous behaviour in the sow and thus have negative impact on piglet survival. The scores for sow communication and carefulness were highly correlated, suggesting that we could merge them into one score for future studies and use this score in a breeding program. However, so far, we have not been able to calculate heritability for those important behavioural traits, and neither for the teat pair distance. We hope that some breeding companies would like to collaborate with us to calculate the genetic basis for these traits and then to implement them in the breeding program as these traits appear to have a huge impact on piglet survival and welfare. If the maternal behaviour is optimal this would also lead to less work for the farmer at the time of farrowing.

To provide the sows with free access to relevant nest building material around 12 hours before expected parturition is an excellent routine to improve the maternal motivation in sows. Which material is best suited can be discussed (e.g. Thodberg et al., 1999), but at least when comparing peat with long-stemmed straw, straw resulted in a greater variety of nest building behavioural elements, increased time spent resting and reduced the incidence of oral stereotypies compared to sows that had access to peat or only sawdust (control=minimum amount of sawdust for hygienic purposes is manifested in the Norwegian legislations) in the pen (Rosvold et al., 2018). During farrowing, sows provided with straw or peat as nesting material show a lower frequency of negative communication towards piglets compared to controls (Rosvold et al., 2019). Straw as nest building material also resulted in a higher proportion of sow-initiated nursing bouts and successful nursing bouts (i.e. with milk let-down) than sows in the peat and control groups. We have also found a shorter farrowing duration compared to sows provided with peat or no specific material, and percentage of stillborn was lowest in the straw group (Rosvold & Andersen, 2019). Another important point to make is that the positive effects of nest-building are also depending on enough space to move around and perform the behavior in a satisfactory way, as for instance crated sows still show bar biting and restless behavior even if they have the same amount of straw as sows in pens (Andersen et al., 2014). This ultimately means that provision of nest building material cannot compensate for the frustration of being confined. Altogether, it thus appears to be a good strategy for stimulating maternal motivation and investment to provide the sows with relevant and enough nesting material with a correct timing prior to parturition. For practical purposes, we recommend that straw is provided from a hay rack with a solid bottom plate and 8-10 cm openings between the rails so that the sows have to work a bit to get it out and to avoid spoiling too much onto the floor and into the slats.

There have been many attempts to develop farrowing pens that meet behavioural needs of sows. The Australian Werribee pen developed as early as in the late 1990s resulted in similar or even lower mortality rates than crates in commercial as well as experimental farms (e.g. Cronin, 1997a; Cronin et al., 2000), and promising results have also been achieved with the FAT2 pens in Switzerland (Weber et al., 2007). An outdoor system with huts could be considered as the most stimulating environment for sows and piglets, but this system is not a realistic alternative in many places due to climatic conditions and because the mortality rate may vary to a large extent. Indicators of piglet survival and the sow traits needed in such a system may be different from an indoor environment (Baxter et al., 2009). In addition to another sow genetic material, this system would require excellent management skills from the producer. More recently developed pens, such as the PigSafe pen, suggest that the nest area should not be too large in order to minimize preweaning mortality. Comparatively, Cronin et al. (1998), suggested that the width of the nest area should be at least 2.2 m, to make it easier for the sow to orientate and nurse. This is also why we chose a pen width of 2.4 in the SowComfort pen decribed below. What is also worth mentioning is that piglets born in the PigSafe pen showed more play behaviour pre-weaning and less aggressive behaviour post weaning than piglets born in a crates (Baxter et al., 2015), suggesting that a more stimulating birth environment may have important developmental effects on piglets.

There are no longer good arguments to confine sows in terms of piglet survival, but there may still be different causes of death in the different systems (Weber et al., 2009; Baxter et al., 2011; Pedersen et al., 2011). In Norway, mortality rate of liveborn piglets in individually loose housed sows have become as low as 12% (InGris National data base, 2019), although number of liveborn piglets are relatively high, with an average of around 14 piglets. Norway banned crates already in 2000, and there are many different farrowing pens on the market that works well and with low mortality. However, as discussed later, mortality of live born piglets and the overall production results, are strongly affected by the farmers management, and more so than the pen design itself. A recent study revealed that crated sows had more locomotion problems and udder lesions, and that the piglets had more skin lesions on their face and carpus than in farrowing pens (Lohmeier et al., 2019). Furthermore, the suckling duration per suckling bout in the same study was longer in the pen system than in crates. From what we know about maternal behaviour of sows, their interactions with piglets and behavioural needs, we do not consider crates or semi-crated systems as satisfactory housing systems for sows during birth and lactation. These systems will thus not be further considered or discussed in the present paper.

It makes little sense to study size of the farrowing pen per se, as this will be the result of including the design elements necessary for sows and her piglets to behave optimal in a pen. As the sows have become larger and longer, the sows need sufficient space and especially wide enough pens for the sow to turn around and orientate within her nest area, both when performing nest-building behaviour (Cronin et al., 1997b; Damm et al., 2003) and when nursing (Cronin et al., 1998). Larger pens with more bedding material, solid walls and not the least with a deeper slatted floor area results in a better dunging pattern and the cleanest pens (Bøe et al., 2019). This is crucially important as the sow needs space to get out of the rest/nest area and into the dunging area with her entire body. Usually nipple drinkers are placed towards neighbouring pens in such a way that she must orientate with her butt part towards the slats and not standing with her front part in the slatted area and the hind part still placed in the solid floor area. If the area is too small and there is no

clear distinction between resting and dunging area, the sow will not perform in a way to make the pen clean.

To develop an optimal farrowing environment, we need to understand how the design features of the farrowing environment, management and sow maternal traits interact, and find a combination of these three factors that leads to high piglet survival. The best solution is for the sow to take care of her piglets sometimes with extra work on the part of the farmer around the time of farrowing, even if there is some added labour cost. This requires breeding for good behavioural and physical maternal traits as well as provision of key environmental stimuli fulfilling the needs of the sow to perform certain behaviours and to increase sow motivation to protect her young. Confident sows in a positive emotional state, without painful problems, are likely to become the best mothers.

Key features of a farrowing pen are access to nest-building material before farrowing and the provision of sufficient space for the sow to turn around and orientate within her nest area, both when performing nest-building behaviour (Cronin et al., 1997b; Damm et al., 2003) and when nursing (e.g. Cronin et al., 1998). Separate nesting and dunging areas are needed. To encourage the sow to farrow in the nest area, some level of separation from humans and other pigs is necessary. This can be achieved by enclosing three sides of the nest area with solid walls, and providing a non-nesting, activity/dunging area with an open view so that the sow can always see who enters the pen (Cronin et al., 1997a), and the neighbouring sows. Another important objective of the nest area design is to increase the preference of sows to farrow in an area that contains specific features promoting piglet survival. For example, sloped, solid walls within the nest area should be provided for the sow to lean against when descending from a standing posture to a resting position (Damm et al., 2006). The provision of floor heating in the nest area helps new-born piglets to dry faster, reduce heat loss shortly after birth and reduce latency to first suckling. This may result in as much as 7% higher survival rate (Malmkvist et al., 2006). Many farrowing pens are constructed with the assumption that newborn piglets are willing to leave their safe, soft, milk-smelling mother's udder to go to a warm creep area. However, piglets under natural or semi-natural conditions would not leave the safety of the nest and their mother's udder during the first days after birth (e.g. Stangel & Jensen, 1991) as staying as close to the sow as possible would increase survival. Even when there is a high-quality creep area formed like a hut with a small entrance, a thick layer of bedding and automatically controlled heaters, piglets still prefer to rest with their mother for the first two days (e.g. Vasdal et al., 2010). Outside the time of nursing, the sow most commonly communicates to attract the piglets and make them come close to her and stay more in the zone where they can get crushed by their mother, but an increased time spent near the sow in this crucial period does not increase mortality (Melisova et al., 2011). Rather the contrary, the best ticket to survival for a piglet by nature is to stay close to its mother for protection, warmth, comfort and to make sure that an important meal is not missed. Sometimes we tend to misunderstand this biology when we talk about danger zone and that the mother is the source of danger for her young. Maybe we should focus more on how we can stimulate the sow for maternal care? Or find out why sows become stressed and maternal care is impaired in a specific environment?

Excample of a farrowing pen designed to meet behavioural needs of the sow - the SowComfort pen

The SowComfort farrowing pen is as the name suggests designed to meet the sow needs and to stimulate good maternal behavior. There are several essential components that make this a comfortable pen for the sow: she has a separate nest area with walls protecting her against the surroundings, equipped with a mattress that is more comfortable than concrete, floor heating and a hay rack from which both hay and straw are provided. Sloped walls offer support when lying down and protection against piglets being crushed. There is a sharp distinction between the closed nest area and the more open activity area that provides the sow with a good overview of the surroundings and allows the farmer to enter the pen outside the nest area that she is motivated to protect. This ensures predictable handling and a good way for the farmer to approach the sow. It is our understanding that "happy" sows that are in a positive emotional state are also the best mothers and the easiest to handle for the farmer. This can be achieved by playing with the biology rather than against it such as when the sows are left no control of her young in the crate or semi-crated systems and when a separate creep area is provided where the sow cannot see her piglets.

The SowComfort farrowing pen comprises two compartments: a "nest area" and an activity/dunging area. The SowComfort pen provides 7.7 m^2 to allow locomotion before farrowing, and space for piglets from birth to 30 kg after the sow has been moved if this is preferred. The "nest area", covered by a 30 mm thick, hollow rubber mat (Calma; www.kraiburg.com), is designed in a way that allows air space above the concrete floor (Figure 2). This enhances the efficiency of floor heating if insulation is placed underneath the rubber mats on the concrete to reduce conductive heat loss. The reasons for choosing a substantial rubber mat in the nest area were to increase resting comfort of the sow and piglets (thereby the name "SowComfort pen"), to minimise the risk of sow shoulder lesions and lameness, and to minimize knee lesions of the piglets. The activity/dunging area contained the sow feeder and drinker as well as a plastic slatted floor. The slot size was 14 mm in diameter.

The SowComfort pen is designed to facilitate the choice that sows show to farrow at the rear of the pen, in the nest area. They probably make this choice to avoid disturbance, such as that by stock-people who approach the pen from the front. The front dunging area is surrounded by fences made of vertical stainless-steel rods to enable the sow to see her surroundings and provide visual and limited physical contact with neighbouring sows. The SowComfort nest area has solid side walls to provide a closed cave-like environment for the sow and piglets, affording the sow a visual barrier for privacy from neighbouring sow(s) whilst in the nest, and hence some sense of isolation from herd mates. The solid walls and the sloping panels were made of fibreglass, which is a long-lasting, hard wearing material that is easy to clean.

As mentioned above, design features of the nest area have been included specifically to promote piglet survival through good maternal behaviour. For example, in addition to the comfortable mat, the SowComfort pen provides a hay/straw rack for nest-building where the sow can pull out as much material as she is motivated to eat and use. A pilot experiment confirmed that 8 cm openings between the metal bars in the grid of the rack were better than 10 cm openings, because this allowed the sow to place her snout between the bars but required her to spend time dragging the straw out. A solid board at the bottom of the hayrack was preferred to avoid waste on the floor. The sows had free access to hay from the hayrack from one week before predicted birth and throughout the entire lactation period, except for a short period of 24 hours before predicted birth when the hay was replaced with straw for nest building. Uncut straw only was used for the nest building period. After

birth, this allowed any wet sawdust and straw to be replaced by a thin layer of dry sawdust on top of the mat to ensure dry and hygienically optimal conditions for the neonates. At the time of birth, the layer of sawdust was 3-4 mm thick. Two other important features of the nest area are sloping panels along two walls and two, independently controlled, heated-floor zones (Figure 2). Sows prefer to lie against sloping panels when descending from standing to lying posture (Figure 2; Damm *et al*., 2006). Hence, with the ability to control temperature in different floor zones, it is possible to influence where the sow lies relative to her litter. Twenty-four hours before expected birth, both heat zones in the floor of the nest area were set at 34 ºC to provide the piglets with heat irrespective of the birth location in the nest area. Also, early findings show that sows prefer temperatures of around 35 °C the time of birth (Phillips *et al*., 2000). Twenty-four hours after birth, the heat zone towards the end wall of the pen was switched off to make sure that the sows still showed a preference to rest on this particular part of the nest area, even if she had reduced her temperature preference as her milk production increased. The under-floor heat zone towards the right short wall of the nest area was maintained at 34 ºC for most of the lactation period, just being reduced to 30 ºC in the last week of lactation, in order to stimulate the piglets to choose this location for resting when not nursing. This wall is too short for most sows to lean against, and thus most sows preferred the area towards the back wall or the centre of the nest. Room temperature was kept at 18-20 ºC during the data collection and artificial light was kept on between 0730 and 1430 hours.

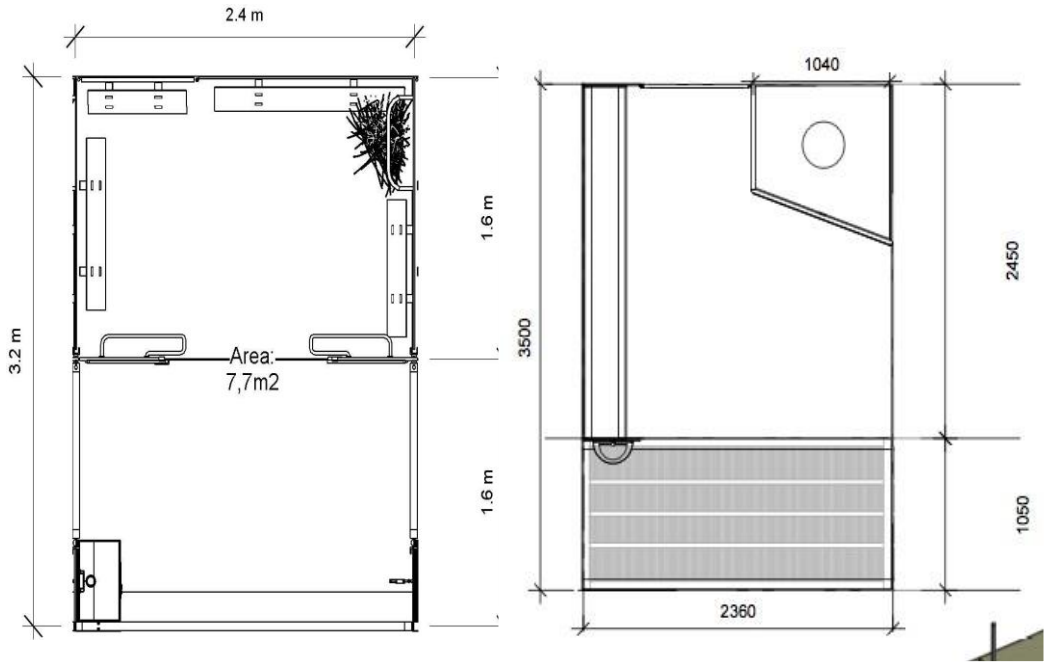

Figure 1. SowComfort pen to the left vs a typical, Norwegian farrowing pen with creep area to the right. The latter had a long through for feeding sows and piglets.

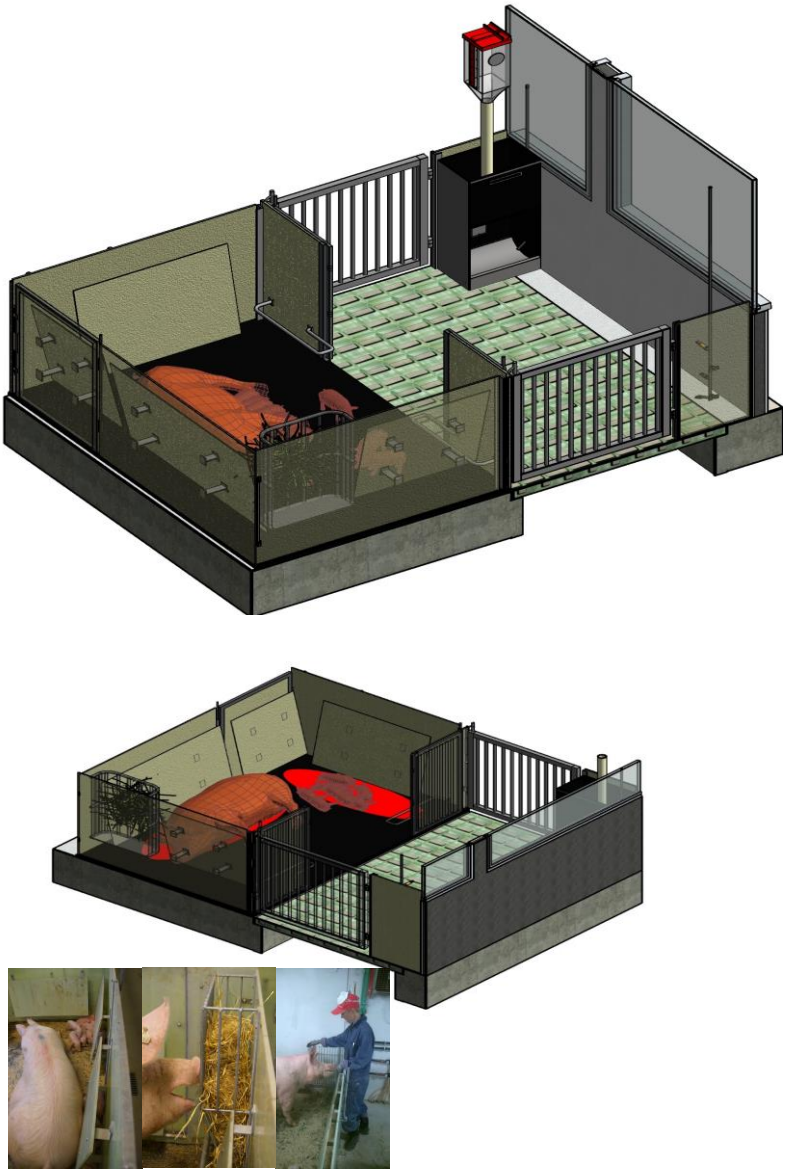

Figure 2. Details of the commercial version of the SowComfort farrowing pen with floor heating areas, rubber mattress on the solid floor, sloped walls in the nest area, hay/straw rack for roughage feeding and nest building material in the nest area. The open design facilitates a good overview for the sow, good contact with neighboring sows and the farmer as the farmer always should enter the pen from the slatted floor area. Drawings were made by Elsbeth Morland in Fjøssystemer A/S.

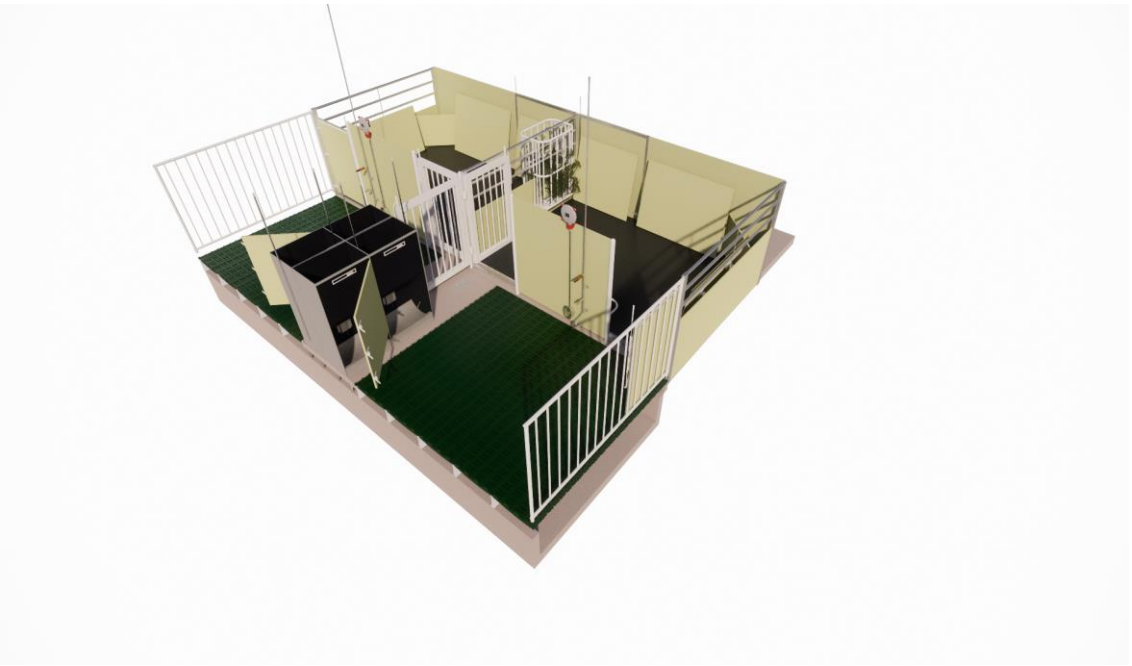

Figure 3. Commercially improved version of the SowComfort pen with a slightly deeper slatted floor area (10 cm added) and an extra feed dispenser to make an optimal "from birth until 30 kg" pen for the piglets, meaning that the piglets can remain in the birth environment until 30 kg while the sow is removed after weaning at the age of around 5 weeks (legislation demand is no less than 28 days). Drawing was made by May Helen Gryte in Fjøssystemer A/S.

To test the SowComfort pen in a commercial setting, we selected two commercial herds that wanted to build a new farrowing section. From the first commercial herd, we collected data from 162 healthy LY sows of different parities and their litters, of which 61 litters were from three different batches in an old pen system vs. 101 litters were from four different batches in the SowComfort pen (Figure 1). In a second herd, we collected data from 156 healthy LY sows and their litters distributed between three different batches kept in an old pen system. We collected production data from 343 healthy sows with different parities in the new pen, distributed between 7 consecutive batches. The data within each of the two herds were analyzed separately as they differed in management routines, and we used a generalized model in SAS.

Production results showed that % mortality of live born piglets was around 13% in both pen systems in the first herd but causes of mortality in the two pens differed. While the SowComfort pen resulted in lower mortality (1.7 ±0.5%) due to starvation (i.e. no milk in the stomach), more piglets were crushed in this pen compared to the old system (SowComfort pen: 11.8±1.4% vs. old pen system: 9.6± 1.2%). In the same herd, percentage of piglets per litter without knee lesions were significantly higher in the SowComfort pen (28.8±3.1) than in the old pen system (11.0±2.4; $P<0.0001$), indicating that the rubber mattress provides more protection than concrete floor with sawdust.

In the second herd, where we had the opportunity to collect data from 7 consecutive batches, piglet mortality declined significantly and steadily from 15.4±1.6% in batch 1 to as low as 11.7±1.6 in batch 7 (P<0.0001; Table 1; Figure 4), with the routine that farrowings were usually attended during daytime (80%), but not during the night. Also, sows that had no problems during the farrowing or early nursing, were left as undisturbed as possible. At present, the mortality rate in this particular herd is around 10% with little extra workload at the time of farrowing. Mortality of liveborn piglets was significantly lower in the SowComfort pen (P<0.0001) compared to the old pen system (Figure 4), and primiparous and second parity sows had the lowest mortality (P<0.0001). Mortality due to starvation was rare while crushing was the most common cause of death.

Table 1. Production results from a commercial herd in the first 7 consecutive batches after installing the SowComfort pen.

SowComfort, 2nd herd	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7
No. of live born per litter	14.5±0.3	14.6±0.3	14.3±0.4	15.7±0.2	13.4±0.3	13.8±0.3	14.2±0.2
Mortality of live born %	15.4±1.6	15.1±1.3	13.0±1.8	**12.3±1.6**	**12.4±1.3**	**12.4±1.8**	**11.7±1.6**
Stillborn %	2.9±0.7	4.8±1.0	4.5±1.2	5.5±1.1	4.6±0.8	6.3±1.2	6.5±1.5
Dead without milk %	3.6±0.7	2.1±0.6	1.0±0.3	1.7±0.6	0.2±0.2	0.7±0.4	1.3±0.5
Overlain %	9.8±1.4	12.1±1.4	10.7±1.7	9.1±1.4	10.7±1.3	9.9±1.8	7.8±1.2
Other causes %	2.7±0.6	0.7±0.3	1.1±0.3	1.7±0.6	1.5±0.5	2.1±0.7	2.4±0.8
No. of weaned piglets	12.2±0.3	12.4±0.2	12.5±0.4	12.3±0.2	13.8±0.4	11.7±0.4	12.2±0.2

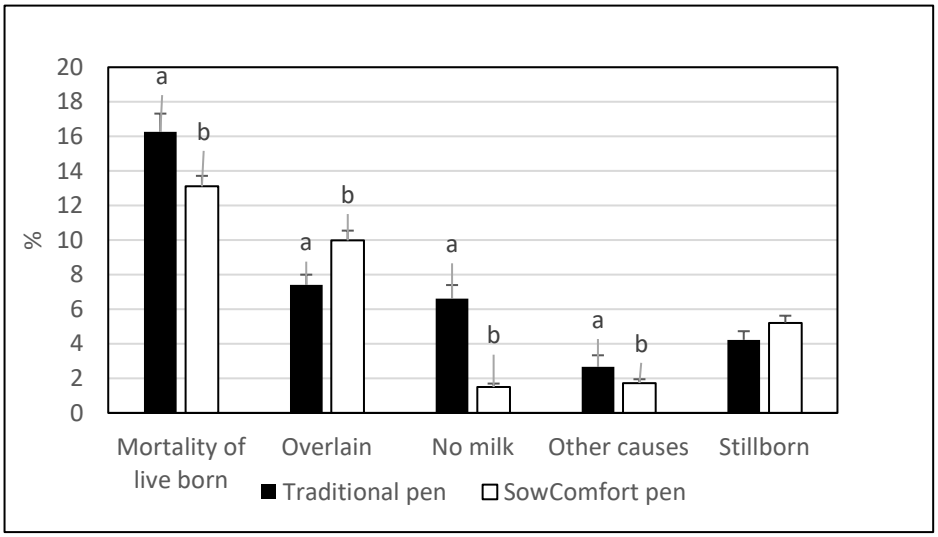

Figure 4. Causes of preweaning mortality in a traditional, individual loose-housed sow pen with a separate piglet creep area compared to the SowComfort pen with a nest area for sows and piglets together and no separate creep area.

Impact of management

To have a functional farrowing pen where the sow is stimulated for maternal care and she has a comfortable place to rest and nurse, is always an important basis for reaching the goal of high productivity without compromising sow and piglet welfare too much. The principle of "working with the biology" rather than battling against it, is the most clear and important advice we can give. Understanding the behavior of the sows and piglets, their activity pattern, their defecation and urination habits, how they communicate etc., are the most important criterias for designing pen systems and for making a list of routines necessary to succeed with this sensitive but fascinating biological system. Loose-housing requires a good human-animal relationship where the sow shows confidence towards the stockperson. To achieve a good relationship with the sows and piglets and positive handling practices, the stock person must show consistent and predictable behavior and attitudes, patience, reinforce positive behavior by petting, friendly talking, and maybe even use treats. What does it really mean to behave in a friendly and respectful way towards the animals while conducting the everyday routines? If you know the answer of that question, there should be less reason to worry about taking the full step from crates to pens where the sow is kept 100% loose. Good, consistent routines around the time of farrowing has major impact on piglet survival until weaning (reviewed by Kirkden et al., 2013). Our recent results from a large survey in 52 Norwegian loose-housed sow herds showed that farmers that attended at least 80% of the farrowings, had frequent positive contact with the sows, dried newborn piglets whenever necessary, and practised split suckling in large litters, had the lowest preweaning mortality (Rosvold et al., 2017). However, split suckling is time consuming especially during batch farrowing when many sows give birth to large litters. When the farrowing pen and creep area is designed in a way that do not protect the piglets from heat loss immediately after birth, piglet survival can be substantially improved by drying the piglets and placing them under a heat lamp (Andersen et al., 2009). This ultimately means that the negative effects of a suboptimal pen can to some extent be compensated by good management practises. Sows that are confident with the stock person and has positive associations with that person is also likely to have fewer negative

responses to being assisted during farrowing and will more easily accept that the farmer handles her piglets. This is considered of crucial importance in our commercial farms, and Norsvin (the national breeding company in Norway) is now planning courses in how to observe and interpret behaviours of the pigs in order for the farmer to collaborate more with the animals and have a positive impact in their everyday work at the farm.

The best practice around the time of farrowing can be summed up as follows: 1) make sure that the sow has free access to nest building material around 24 hours before expected parturition (or for the ones that knows the behaviour of their sows: at the time when the sow starts to show restless behaviour from 12 to 6 hours prepartum), 2) the pen should be clean and there should be a generous amount of litter at the time of farrowing, even when using a mattress, 3) the sows that are doing a great job themselves should be left as much in peace as possible, and 4) when present at the time of farrowing, the farmer can assist when the birth process is prolonged and difficult, may prevent crushing during near-crushing accidents, and finally may assist the new born piglets that are lost on the slats or dunging area and needs to be dried and placed at the udder or close to a heat source. 5) Cross fostering of larger piglets is a good routine if some piglets do not get access to a teat (e.g. reviewed by Kirkden et al., 2013), but should not be practised if the sow can feed her entire litter. Artificial rearing is not a good alternative to being reared and nursed by a sow as it impairs behaviour (i.e. more belly nosing, oral manipulation, less play and exploration, lower emotional status), welfare and growth of the piglets (Schmitt et al., 2019).

Conclusions

To answer the question “Why should we worry about farrowing systems for sows?”, our claim is that we both have enough scientific knowledge and practical experience in some countries that have had loose housing for many decades, that we should not have fear towards letting the sows loose and choose systems that prioritize good animal welfare. It is more a question of the quickest route to share existing knowledge so that it can benefit the animals and stockpersons at the present stage and not far in the future. To satisfy behavioural needs during confinement is hardly possible, and crates or semi-crated systems should thus be banned altogether because of this, especially when we know that similar production results can be achieved without compromising welfare so much in loose-housed sow pens. While a good pen design forms an important basis for producing high quality litters, we still should keep in mind that it is the sow maternal traits and the management practices that has the largest impact on sow productivity and piglet survival in loose-housed sow herds. This is also why we always should keep track of side-effects of selection and make sure that breeding programs include traits that increases robustness and longevity, and that animal keepers and stock persons have enough competence about welfare as well as productivity.

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