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The effect of pen design on pen floor cleanliness in farrowing pens for loose housed lactating sows

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Declaration of interest
None

Abstract

The aim of this study was to investigate the effects of design of farrowing pens for loose housed sows on dunging pattern and pen cleanliness. Thirty commercial pig herds in Norway were visited by a trained observer. Pens were divided into five sectors and the amount of dung in each sector (score 0 – 3), and the proportion of sector covered with dung, were scored. Pen cleanliness indices (PCI) were then calculated for a total of 317 pens, using two models. For Model B, the PCI^B varied between herds from 1.2 in the herd with the cleanest pens to 10.4 in the herd with the dirtiest pens. However, variation within herds was also large. For the 5 herds with the lowest PCI^B, the pens were on average larger, had a proportionally larger area of slatted floor, were provided with more bedding material and the pen side walls were solid.

Keywords: loose housed sows; farrowing pens; floor cleanliness

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1. Introduction (669 words)

According to Norwegian (Forskrift om hold av svin, 2003, § 11), Swedish (Djurskyddsförordning, 1988, § 14) and Swiss animal welfare legislation (Tierschutzverordnung, 2008, Art. 50), sows should be kept 'loose' around parturition and during lactation. For compliance, this requires sows to be loose housed in farrowing pens and not confined in a farrowing crate both during farrowing and lactation. Further, the lying area for the sow should consist of solid flooring, and an 'adequate' amount of bedding material should be supplied. However, the pig industry in most countries is predominantly based on confinement of the farrowing/lactating sow in crates (e.g. Morrison et al., 2011; Baxter et al., 2012; Hales et al., 2014). In addition to the general concern about increased piglet mortality and the greater cost of larger farrowing pens for loose housed sows, many pig producers are concerned about poor hygienic conditions in farrowing accommodation with solid floors, and the increased work load required to remove manure (e.g. Moustsen et al., 2007). An investigation involving 35 commercial Swedish pig farms (Mattson et al., 2004) reported that 33% of the total daily work time of stockpeople was required for cleaning of farrowing pens and providing new bedding. Hence, it is important to design farrowing pens that facilitate the development of dunging patterns by the sow and her piglets which minimize labour for cleaning out.

Stolba and Wood-Gush (1989) studied pigs in semi-natural environments and found that when pigs left the nest in the morning, they did not defecate closer than 5 m from the nest and not further away than 15 m. The bigger the area provided to pigs, the larger the area they use for excretion, suggesting that pigs will excrete in any space not used for other activities (Baxter, 1984). Observations in a production environment showed that piglets avoided excreting in the nest/lying area two to six days post-partum (Buchenauer et al., 1982/83, Petherick, 1982/83; Whatson et al., 1985) and that the piglets excreted standing close to a pen wall and particularly in corners (Petherick, 1982/83). The challenge is then to determine what the pigs will excrete away from. Introducing grower-finisher pigs to a round pen (i.e. without corners), Baxter (1982/83) found that pigs excreted near the drinker, but only to avoid excreting on the lying area. This is supported by Mollet and Wechsler (1990), who in addition concluded that pigs prefer to excrete near a pen wall/corner, at locations where there was moisture/liquid and where they could see the pigs in the neighbouring pen. However, Hacker et al. (1994) found that pens with closed partitions were cleaner than pens with open partitions, whereas location of the nipple drinker and animal density had no effect on pen cleanliness. Wiegand et al. (1994) showed that the shape of the pen did not affect the proportion of the pen used for defecation, but noted that pigs in all pen shapes included corners in their defecation areas. Moustsen and Jensen (2008) modified the farrowing pen by adding a wall between parts of the lying and dunging area, which apparently resulted in more excreta deposited in the dunging area. It is also interesting to note the large individual variation in dunging patterns in loose-housed lactating sows (Bøe et al., 2016).

In several studies of cleanliness in pens a scoring system for the amount of excreta has been used, but both the definition and number of categories differ (e.g. Randell et al., 1983; Hacker et al., 1994; Rantzer et al., 1999; Wallgren et al., 2019). Hence, no standard method for recording pen cleanliness is available. Further, quantitative methods such as weighing the excreta seem to be inconvenient. When using bedding material on a solid floor, the floor and bedding may become wet and contaminated from urine, which of course are relevant to pen cleanliness and hygiene, making it necessary to propose a more-relevant scoring system.

The aim of this study was to survey a range of commercial pig farms, to investigate the effects of design of farrowing pens for loose housed sows on pen floor cleanliness associated with dunging patterns of sows and their litters.

2. Material and methods

Thirty commercial pig herds in the south-eastern part of Norway were visited by a trained observer between December and April. The farms were selected based on the criteria that they had farrowing pens for loose housed sows and had a batch farrowing system so that at least eight litters were expected to farrow within five days.

Observations were conducted between 07:00-09:00 h on a total of 317 farrowing pens, when the litters were between three and five weeks of age (mean = 3.6 weeks post-farrowing). The observations were conducted in the morning before the stockperson had cleaned the pens. Prior to the visit, the stockperson had been instructed not to do any cleaning of the pens from 17:00 h the day before. The normal routine is to clean the pens in the morning.

2.1 Pen design

In each herd, the observer measured the inside length and width of the pen, inside length and width of the slatted floor (if any) and the creep area (figure 1). The mean width of the pens was 2.15 m, the mean depth was 3.05 m and the mean total space (depth * width) was 6.58 m^2 (table 1).

Figure 1 here

Table 1 here

A digital level (Bosch DNM 60L) was used to measure the slope of the solid floor area. In the vast majority of the herds (27 of 30 herds) the solid floor area had a slope of 2–4%, whilst in one herd the slope was < 1% and in two herds the slope was > 4%. The majority of the herds (24 herds, 80%) had slatted floors in the dunging area of pens, and in these herds the slatted area on average represented 30.9% (range 19.4 – 40.0%) of the total pen area. Three herds used plastic slatted floors, four had slatted floors made of galvanised steel, eight had cast iron floors while nine had concrete slatted floors. For the 24 herds with slatted flooring in the dunging area, mean width of the void between slats in pens was 11.8 ± 0.6 mm (range 10–20 mm); overall, 15 herds had slatted floors with a 10 mm void between slats. Only one herd had slatted floors with width of slats > 15 mm (actual void width was 20 mm).

The drinker was located on the side wall in the dunging area in 25 herds, on the end wall in the dunging area in three herds and in two herds the drinker was located on the side wall of the lying area. In all herds, the end wall in the dunging area of the pen was solid. However, the type of side wall in the dunging area varied between farms; side walls were categorized based on: 1) solid side walls (n = 9), 2) partly solid side walls (n= 18) and 3) fully open side walls comprised of mesh or bars (n = 3). In all cases, bars were in the vertical orientation within non-solid side walls.

In 17 of the herds, wood shavings were used as bedding material, while 10 herds used sawdust, two herds used a combination of wood shavings and straw and one herd used a combination of sawdust and straw. In order to estimate the ‘typical’ amount of bedding provided in the farrowing pens of the respective herds, a randomly chosen pen was totally cleaned out and all the retrieved bedding material was placed in a large basket and levelled without compaction. The basket was marked with volume lines to enable estimation of the amount of bedding. The stockperson was then asked to add an appropriate daily amount (i.e. what they usually provided) of bedding to the pen. The mean amount of bedding was 8.7 ± 0.9 l/pen (range 4–25 l/pen).

2.2 Ventilation and air temperature

A sketch of the room was made, and the positions of inlets and outlets of the ventilation system were marked. All herds had mechanical ventilation, but the air inlet system varied between herds including wall inlets, ceiling inlets, diffusing inlets in the ceiling and air mixers. In six herds the ambient air temperature was between 14-17 ºC, while for the remaining herds the air temperature ranged from 18–21 ºC.

2.3 Pen floor cleanliness scores

Before going to the herds, the observer was trained in all procedures in the university herd. During the visit, the observer used a scoring system to record the cleanliness of the floor in 6-12 randomly-chosen farrowing pens at each farm, via two related methods for estimating the amount of dung (see Bøe et al., 2016). The pens were divided into five sectors (figure 1), and the amount of dung (D) (partly modified after Hacker et al., 1994) in each sector, and the proportion of the sector covered with dung (P), were scored according to the following categories:

<u>A) Amount of dung (D) in sector</u>

0. No dung on the floor

1. Small amount(s) of dung on the floor

2. Moderate amounts of dung on the floor

3. A lot of dung on the floor

B) Proportion of pen sector affected by the presence of dung (P)

1. < 1/3
2. 1/3 < 2/3
3. > 2/3

In pens without slatted floor, the depth of sector 5 was set to approximately 1 m, close to the mean depth of the slatted floor. The cleanliness score for each sector (SCS – sector cleanliness score) was calculated by multiplying the score for the amount of dung (D) by the proportion of the area of the sector that was contaminated (P). Hence, the maximum SCS was 9.

In order to calculate an overall pen cleanliness index (PCI) for each pen, each of the 5 pen sectors was assigned a weighting factor. Preferably, sows and piglets should dung in the sector containing slatted flooring, and / or where it is most ergonomically convenient for cleaning by the stockperson. Two PCI models were developed and submitted to statistical analysis, to identify factors relevant to overall pen cleanliness. Ideally, sectors further away from the preferred dunging area should be ‘cleaner’, and thus dung recorded in those more-distant sectors received a higher ‘penalty’ score, achieved through multiplication with weighting factors. Model A (PCI^{A}) included dung recorded in sector 5, that is, the intended dunging area of the pen (figure 1). PCI^{A} was calculated for each pen by summing the 5 SCS, following multiplication of the individual SCS by weighting factors for sectors 1 & 2, 3 & 4, and 5 of 3, 2 and 1, respectively:

$PCI^A = D1*P1*3 + D2*P2*3 + D3*P3*2 + D4*P4*2 + D5*P5*1$ (1)

Hence, the minimum pen cleanliness index score (PCI^A) was 0 and the maximum was 108.

The second approach (Model B) was considered as a way of not 'penalizing' sows for dunging in the intended sector of the pen (sector 5). For Model B therefore, the SCS for sector 5 was excluded by setting the weighting factor at zero (i.e., the intended dunging area of the pen; figure 1). The weighting factor for sectors 3 & 4 was one, and for sectors 1 & 2 was two. The sector cleanliness score for each sector was then multiplied by the weighting factor and all scores were summed:

$PCI^B = D1*P1*2 + D2*P2*2 + D3*P3*1 + D4*P4*1 + D5*P5*0$ (2)

where D1 refers to the dung score for sector 1, D2 refers to the dung score for sector 2, and so on. Hence, the minimum pen cleanliness index (PCI) was 0 and the maximum was 54.

However, so as not to lose information about those factors that may have either encouraged sows and piglets to dung in the appropriate sector of the pen (sector 5), or to assist in the removal of dung in that sector through sows or piglets walking on the dung and pushing it through the slatted floor, the SCS for sector 5 (SCS_5) was analysed separately, on the basis that these possible outcomes may be preferred by the farmer.

2.4 Statistics

Data obtained from scoring the amount of dung and the proportion of pen affected by dung were analyzed using Ordinal Logistic Regression with random effects in ASReml using the multinomial cumulative function. Pen cleanliness indices (PCI^{A} and PCI^{B}) and SCS for Sectors 1 & 2, Sectors 3 & 4 and Sector 5 were analysed using Restricted Maximum Likelihood (REML) modelling within GenStat (v17, VSNi). For both types of modelling, fixed effects considered for inclusion in the final model were: Litter age, Ambient temperature, Brand, Pen width, Pen depth, Pen area, Depth of slatted area, Width of slats, Void width, Floor slope, Bedding, Amount of bedding and Type of slats. Random effects included in the model were the terms Herd, Pen and Sector; more specifically, these terms were nested within each other so that the Random model was: Herd/Pen/Sector. All variables were tested in a univariable model and those with P values <0.25 were considered for inclusion in the multivariable model. A stepwise backwards elimination approach was conducted whereby the least significant term was removed from the model until only significant terms remained. Terms with a P value <0.1 were considered significant in the final model due to the large number of initial terms for inclusion. Predicted means, standard errors and Odds Ratios were determined from the final model. As a result of the large number of levels for most variables, each variable was categorized into a reduced number of levels for analysis as shown in table 2.

Table 2 here.

Analyses of SCS for Sector 5 (preferred dunging area) were also conducted to supplement the information about pen cleanliness analysed under Model B, since sector 5 data were omitted from Model B.

3. Results

3.1 Variation in floor cleanliness within pens

Approximately half the pens received a sector cleanliness score (SCS) of 0 (i.e., totally clean) in sector 1, but very few farrowing pens were awarded a score greater than 2 (table 3). The creep area (sector 2) was generally rather clean, with 84.2% of the pens with an SCS of 0. In sector 3, however, only 30.6% of the pens received an SCS of 0, and nearly 64% of the pens received an SCS of 1 or 2. Sector 4 was somewhat cleaner, with 45.7% of the pens getting a SCS of 0. Nevertheless, for < 5 % of the pens an SCS > 2 was calculated in sector 3 and 4. As could be expected, very few pens were scored as 'completely clean' (SCS = 0) in the dunging area (sector 5). The majority of the pens were scored 1 or 2, and only 7% of the pens were scored more than 2 in this sector. The average SCS for sector 5 was 1.4 (± 1.09) and the median was 1 (range 0-9).

3.2 Dung score analysis

3.2.1 Amount of dung on pen floor

The depth dimension of slatted floor area in pens significantly ($P = 0.018$) affected the amount of dung recorded, such that with a greater depth of slatted floor, dunging score was likely to be lower (figure 2). For example, compared to pens without slatted flooring, pens with a slatted floor depth greater than 1 m were 3 times more likely to have a lower dunging score. There was a weak effect of room temperature ($P = 0.1$) on dunging score; compared to temperatures greater than 19°C, dunging score was 3.6 times more likely to be lower, although not significantly lower, compared with temperatures in the range 15.1-17.0°C. No other pen variables significantly modified dunging score.

3.2.2 Proportion of pen floor affected by dung

Similarly, the depth of the slatted floor area in pens also affected ($P = 0.039$) the proportion of the pen in which dung was present (figure 3). For example, compared to pens without slatted flooring, pens with a slatted floor depth greater than 1 m were almost 3 times more likely to have a lower dunging score. Further, apart from floors with concrete slats, the dung scores were significantly lower for all types of floor slats when compared to pens that did not contain slats (figure 4). There were no significant differences in proportion scores between all other comparisons of slat types. The material from which the floor slats were manufactured tended to affect dung score assessed via proportion of affected flooring ($P = 0.10$).

3.3 Pen cleanliness index (PCI)

3.3.1 Model A

Under Model A, the depth of the slatted floor area affected ($P = 0.015$) the overall measurement of pen cleanliness, as shown in figure 5. For example, compared to pens without slatted flooring, pens with a slatted floor depth which was greater than 1 m, were more than 3 times more likely to have a lower dunging score, that is, were assessed as “cleaner”. Pen dimensions (width or length), indoor air temperature, slat width, void width, slope of the floor, type of slat and bedding type did not affect PCI^A, although there was a weak effect due to pen area ($P = 0.064$) on PCI^A.

3.3.2 Model B

Under Model B, which excluded SCS_5, slat depth was not significant ($P = 0.128$) and was dropped from the model. Pen area ($P = 0.064$) and quantity of bedding ($P = 0.096$) both tended to affect pen cleanliness, for example with PCI^B decreasing as pen area increased. The remaining factors such as pen dimensions (width or length), indoor air temperature, slat width, void width, slope of the floor, type of slat and bedding type did not affect PCI^B. Analysis of factors influencing SCS_5 showed no effects ($P > 0.05$) due to any factors. While there were also no effects of pen factors on $SCS_{3\&4}$, there was a significant effect of pen area ($P = 0.019$) on $SCS_{1\&2}$. As pen area increased, sectors 1 and 2 combined were more likely to be cleaner.

3.3.3 PCI across farms

The herd with the cleanest farrowing pens had an average PCI^A of 3.17 and PCI^B of 1.16, while the herd with the dirtiest pens averaged 20.00 and 10.38, respectively. However, the variation within herds was also large. For example, in 17 of the 30 herds, there was one or more pens with a PCI^A of ≤ 1 and in 26 of the 30 herds, there was one or more pens with a PCI^B of ≤ 1, while in 25 herds there were one or more pens with a PCI^A of ≥ 8 and in 10 herds there were one or more pens with a PCI^B of ≥ 8. Across all 317 pens assessed in the study, the mean pen cleanliness index under Model A (PCI^A) was 7.3 ± 5.73 (median 3; range 0-43) and under Model B (PCI^B) was 3.4 ± 3.18 (median 3; range 0-25).

Table 3 here

Interestingly, for the 24 herds with slatted flooring in the dunging area of their pens, the mean SCS was 1.16 and only 14.0% of the pens received an SCS ≥ 2. In comparison, for the 6 herds without slatted flooring in the dunging area, the mean SCS was 2.32 and 61.6% were scored $\geq$ 2.

3.4 Effect of pen design on floor cleanliness

Using Model B to avoid 'penalizing' sows and litters for dunging in the designated dunging sector (sector 5), an initial analysis focusing on the 5 herds with the lowest compared to the 5 herds with the highest PCI^B showed that pens in the 5 herds with the lowest PCI^B were on average larger, with a proportionally larger area of slatted floor, were provided with more bedding and the pen side walls were solid (table 4). Similarly, the cleanliness scores in the designated dunging sector (sector 5) were ranked for the 10 herds with the lowest and 10 herds with the highest SCS (mean $SCS_{5:}$ 0.95 and 2.12, respectively). Of the 10 herds with the lowest dunging scores in sector 5, all had slatted flooring, whereas of the 10 herds with the highest dunging scores, only 4 of the 10 herds had pens which had slatted flooring in the pen design.

Table 4 here

4. Discussion

Despite this study involving only commercial swine herds, it is interesting to recognize that the design of the non-confinement farrowing pens differed considerably between herds, both regarding total space (5 – 8 m^2), presence, proportion and type of slatted flooring and also the amount of bedding material (4 – 25 l). While this finding was unexpected, unfortunately we did not survey the participating farmers regarding when they installed their loose pens, why they chose the particular "style", or the capital outlay. Such points could be relevant for future surveys.

In the creep area (Sector 2), the sector cleanliness score (SCS) was 0 or 1 in 99.1 % of the pens. As the sows had no access to this sector, a low SCS could be expected. However, the large litter sizes and piglets 3 – 5 weeks old, might still be a challenge for floor cleanliness also in this sector. For sectors 3 and 4, and especially sector 1, the proportion of pens with a SCS > 2 was quite low. We interpret this as the lying- and activity-area for the sows and piglets generally were relatively clean, but it requires routinely clean out daily. Unfortunately, it is not possible to make direct comparisons with earlier studies, as the various pen floor cleanliness scoring systems are not standardized (e.g. Randell et al., 1983, Hacker et al., 1994; Wallgren et al., 2019).

There were large differences between herds concerning the mean pen cleanliness indices (PCI), regardless of which model we used to examine the data. The PCI decreased or at least showed a tendency to decrease with increasing pen size, the presence of slatted floor in the dunging area and the depth of the slatted floor. In two Danish experiments however, no effect of farrowing pen design on amount of dung deposited on the solid floor (lying area) could be found (Moustsen et al., 2007; Moustsen and Pedersen, 2010). Interestingly, the Danish experiments also showed that even if the sows were standing on slatted floor during 70 – 80% of the dunging occasions (Mousten et al., 2007), the actual proportion of dung deposited on the solid floor was 42% (Moustsen et al., 2007) and the back part of the sow was positioned over the slatted floor area in only 20 -30% of the dunging (Moustsen and Pedersen, 2010). This latter may be a consequence of the sow's body length being relatively long compared to the dimensions of the farrowing pen (McGlone et al., 2004). Hence the sow's options to move around in the pen are actually rather limited (Bøe et al., 2011), perhaps explaining why sows dung on the lying area even if standing with part of the body in the slatted floor area. The general effect of improved pen floor cleanliness with increasing pen size supports this theory. Another interesting design factor that might improve pen cleanliness is to introduce additional pen partitions to better mark the border between the lying and dunging area (Moustsen and Jensen, 2008).

In the present study, location of the nipple drinker had apparently no significant effect on pen floor cleanliness. This is in accordance with Hacker et al. (1994), whereas both Baxter (1982/83) and Mollet and Wechsler (1990) found that pigs preferred to excrete near the nipple drinker.

The concept of having open sidewalls in the dunging area is apparently based on the observation that the pigs in one pen can see the pigs in the neighboring pen, and hence be attracted to excrete in this sector of the pen. Unfortunately, this had no effect in the present study.

Interestingly, pen cleanliness varied considerably within herds. This was most likely due to the large individual differences in dunging patterns described by Bøe et al. (2016).

5. Conclusion

We conclude that the pen floor cleanliness varied considerably between herds, and the PCI decreased with increasing pen size, the presence of slatted floor in the dunging area and the depth of the slatted floor area.

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Tables

Table 1. Pen size, slatted floor characteristics and volume of bedding provided in the different herds.

	Mean	Maximum	Minimum
Total space (m^2)	6.58	8.96	5.04
Depth of pen (m)	3.05	4.00	2.50
Width of pen (m)	2.15	2.50	1.80
Depth of slatted floor (m) *	0.96	1.20	0.60
Proportion of slatted floor to total space (%) *	30.9	40.0	19.4
Width of voids (mm) *	11.8	20	10
Volume of bedding material (l)	8.7	25	4

* Only herds with slatted flooring

Table 2. Variables which were categorized to fewer levels for statistical analysis.

Variable (unit)	Original data set		After revision into fewer categories			
	Range in values	N levels	New levels	New category	Cut off points	% data
Temperature (°C)	14-20	18	4	1	<15.1	8.5
				2	15.1-17	16.4
				3	17.1-19	53.3
				4	>19	21.8
Pen width (m)	1.8-2.5	15	3	1	≤2	32.5
				2	2-2.25	38.5
				3	>2.25	29.0
Pen depth (m)	2.5-4	16	4	1	<2.7	8.2
				2	2.7-3	35
				3	3.1-3.3	48.9
				4	>3.3	7.9
Pen area (m^2)	5.04-7.31	24	5	1	<6	16.7
				2	6-6.5	24.9
				3	6.6-7	28.7
				4	7-7.5	16.4
				5	>7.5	13.2
Depth of slatted floor area (m)*	0-1.2	16	4	1	0	18.9
				2	<0.8	18
				3	0.8-1	36
				4	>1	27.1
Width of upper surface of slats (mm)*	0-55	10	4	1	0	18.9
				2	<13	37.2
				3	13-40	30.6
				4	>40	13.2
Void width between slats (mm)*	0-20	7	3	1	0	18.9
				2	<12	55.2
				3	>12	25.9
Floor slope (%)	0.2-6	20	3	1	<2	37.9
				2	2-3	37.2
				3	>3	24.9

* : a zero measurement indicates fully solid floor without a slatted section

Table 3. Proportion of pens (%) with a sector cleanliness score (SCS) of 0 to 9 in sector 1 to 5.

	Sector cleanliness score									
	0	1	2	3	4	5	6	7	8	9
Sector 1 (%)	52.1	41.0	4.7	0.0	1.6	0.0	0.3	0.0	0.0	0.3
Sector 2 (%)	84.2	14.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sector 3 (%)	30.6	53.9	11.0	0.0	3.2	0.0	1.3	0.0	0.0	0.0
Sector 4 (%)	45.7	39.8	8.5	0.0	4.7	0.0	1.3	0.0	0.0	0.0
Sector 5 (%)	4.1	72.9	15.1	1.0	4.7	0.0	1.9	0.0	0.0	0.3

Table 4. Data for the five herds with the lowest and the five herds with the highest pen cleanliness index calculated using pen cleanliness index model B (PCI^B).

	Lowest PCI^B n = 5	Highest PCI^B n = 5
Mean pen cleanliness/excreta index	1.5	7.2
Indoor air temperature (°C)	18.2	17.7
Total pen space (m^2)	7.3	6.3
Slatted floor (prop. of herds)	4/5	3/5
Prop. of pen area with slatted floor (%)	31	23
Mean floor slope (%)	2.5	3.0
Amount of bedding (l/pen)	8.4	6.2
Pen sidewall solid or partly solid (prop. of herds)	4/5	5/5

Legends to figures

Figure 1 Typical farrowing pen lay-out with the sectors 1 – 5.

Figure 2 Dung score distributions shown as cumulative probabilities of the amount of dung in farrowing pens scored on an ascending scale of 1-3, related to the depth of slatted flooring. Letters at the top of columns refer to statistical differences in pairwise comparisons between specific columns: a,b $P = 0.009$; c,d $P < 0.05$; e,f $P = 0.008$.

Figure 3 Dung score distributions shown as cumulative probabilities of the proportion of farrowing pen floor that contained dung, on an ascending scale of 1-3, related to the depth of slatted flooring. Letters at the top of columns refer to statistical differences in pairwise comparisons between specific columns: a,b $P = 0.015$; c,d $P = 0.007$; e,f $P = 0.071$; g,h $P < 0.05$.

Figure 4 Dung score distributions shown as cumulative probabilities of the proportion of farrowing pen floor that contained dung, on an ascending scale of 1-3, related to the proportion of the floor that was dung-affected. Letters at the top of columns refer to statistical differences in pairwise comparisons between specific columns: a,b; a,c; a,d pairwise comparisons were all $P < 0.05$.

Figure 5 Pen cleanliness/excreta index distributions shown as cumulative probabilities on an ascending scale of 1-4. The figure is based on Model A, which includes all sectors of the pen. Letters at the top of columns refer to statistical differences in pairwise comparisons between specific columns: a,b; a,c; a,e pairwise comparisons were all $P < 0.05$.

Figure 1

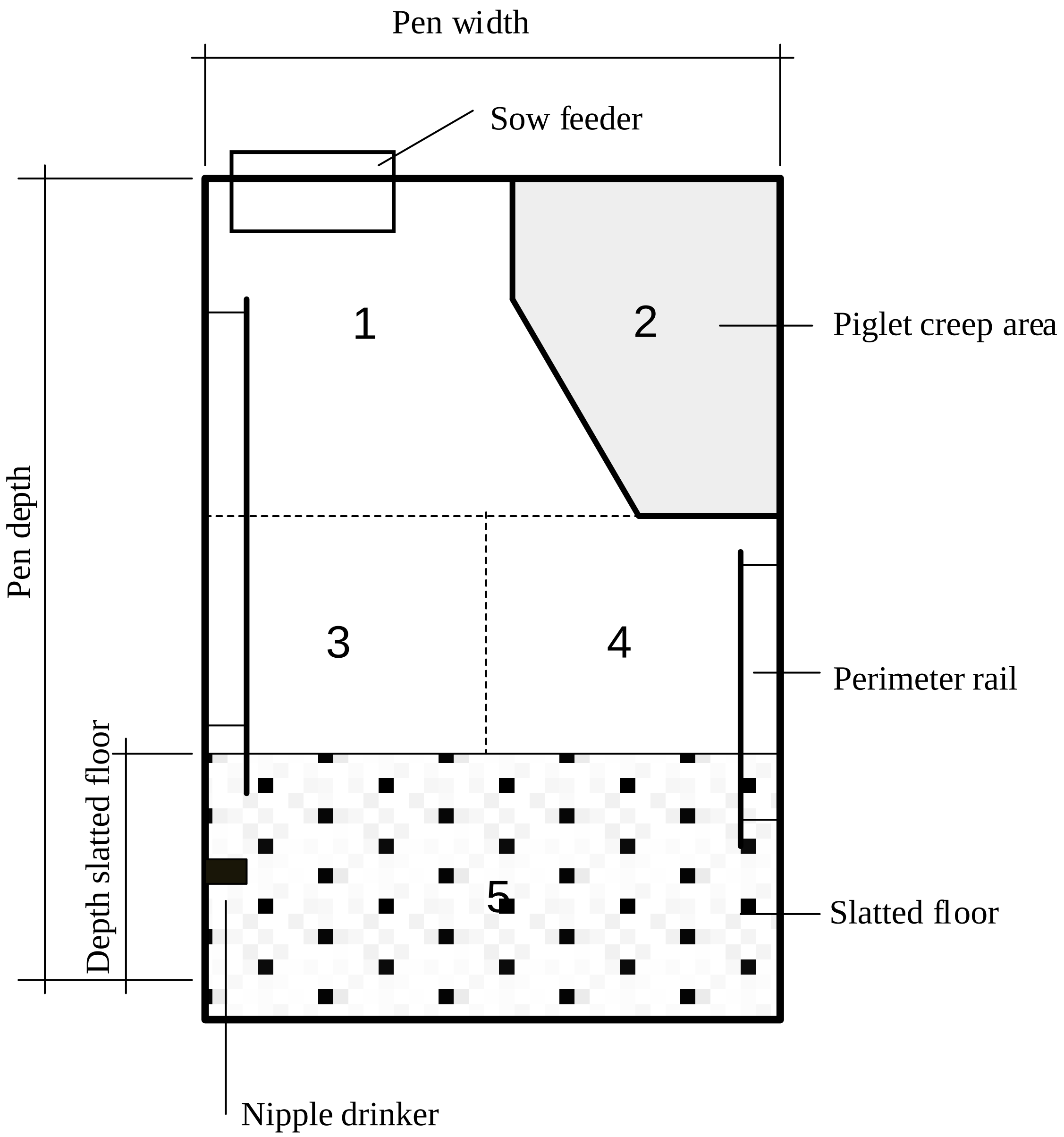

Pen width
Sow feeder
1
2
Piglet creep area
Pen depth
3
4
Perimeter rail
Depth slatted floor
5
Slatted floor
Nipple drinker

Figure 2.

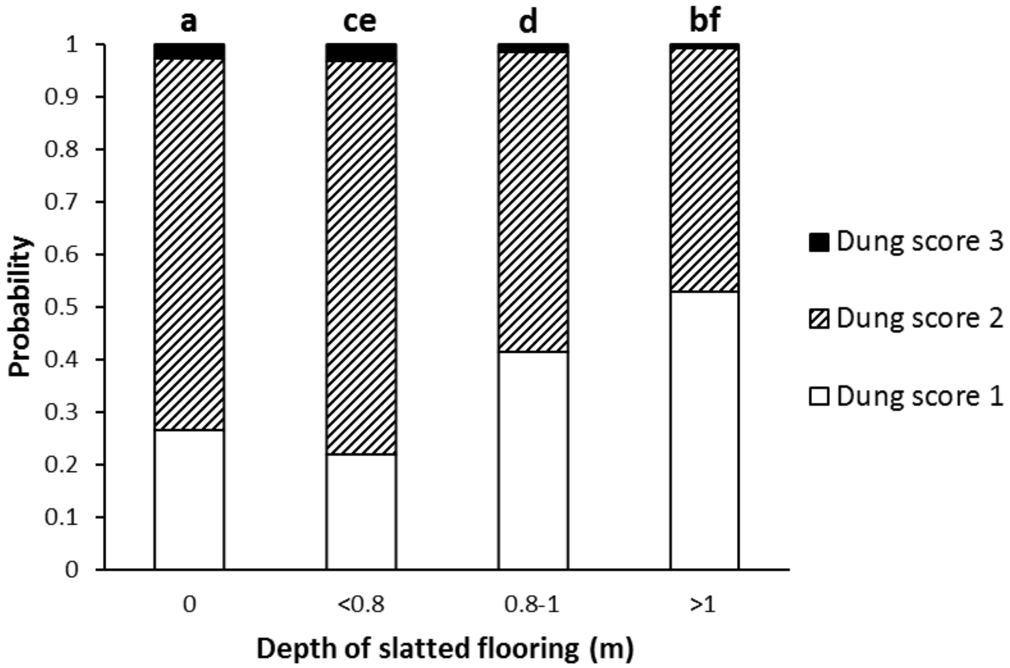
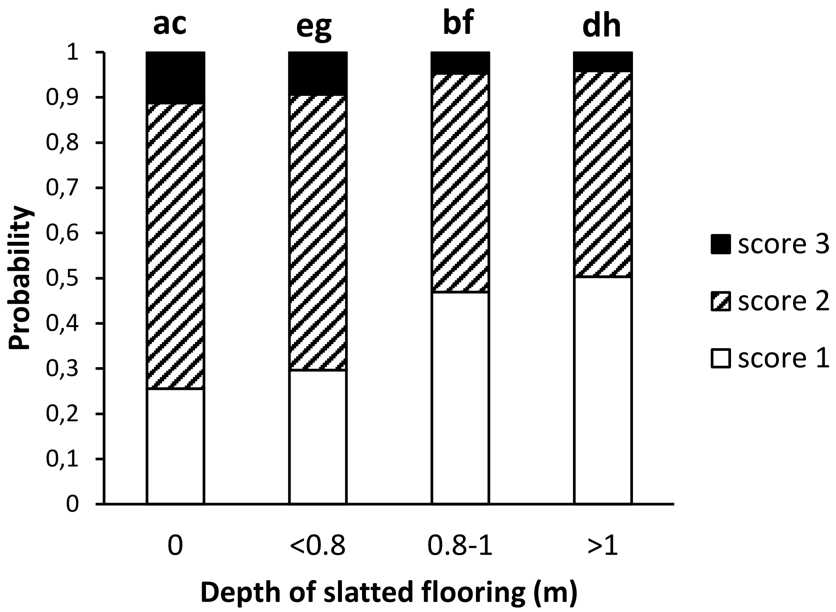

a
ce
d
bf
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Probability
Dung score 3
Dung score 2
Dung score 1
0
<0.8
0.8-1
>1
Depth of slatted flooring (m)

Figure 3.



ac
eg
bf
dh
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Probability
score 3
score 2
score 1
0
<0.8
0.8-1
>1
Depth of slatted flooring (m)

Figure 4.

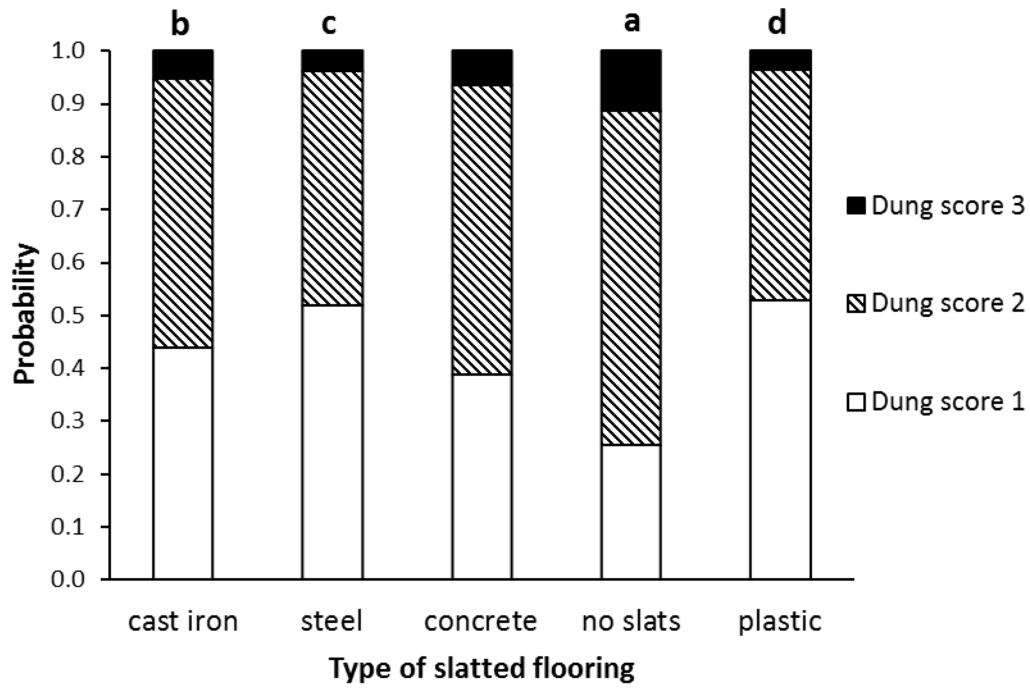
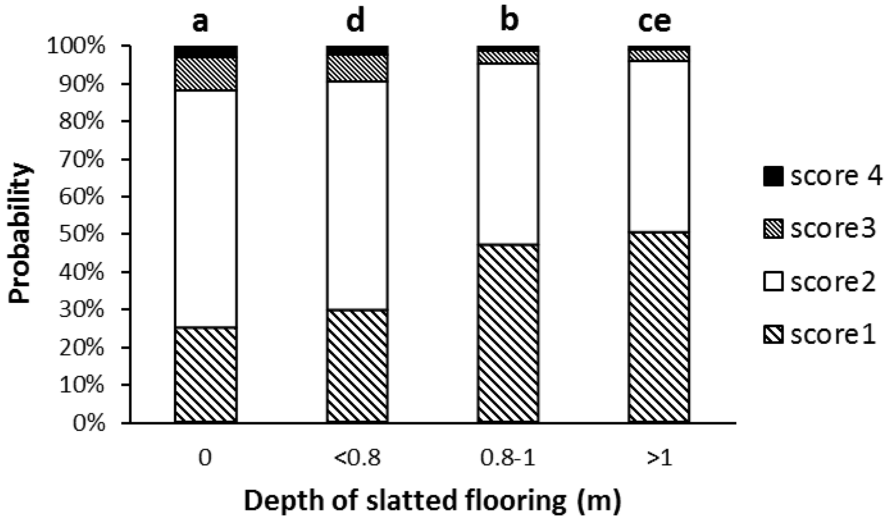

b
c
a
d
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Probability
Dung score 3
Dung score 2
Dung score 1
cast iron
steel
concrete
no slats
plastic
Type of slatted flooring

Figure 5.


a
d
b
ce
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability
score 4
score3
score2
score1
0
<0.8
0.8-1
>1
Depth of slatted flooring (m)