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How do stocking density and straw provision affect fouling in conventionally housed slaughter pigs?

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Abstract

The aim of the study was to investigate when fouling appears in conventionally housed slaughter pigs and whether stocking density and straw provision are risk factors to fouling. During four batches of a total of 112 pens with slaughter pigs, pens were randomly assigned to one level of each of two treatments: (1) 150 g of straw provided per pig per day on the solid floor (n=56) v. no straw provided (n=56), (2) stocking density of 1.21 (n=56) v. 0.73 m²/pig (n=56). Fouling was recorded each day, and a pen had an event of fouling if at least half of the solid floor was wet with excreta and/or urine. Only the first event of fouling for each pen was included, and thus results represent whether a pen had a fouling event or not and when it happened. Data was analysed by using a Cox regression assuming proportional hazard and with right censoring of pens that never developed fouling. First event of fouling was mostly seen during the first week after insertion and in the last 3 weeks prior to slaughter (10 week study period). Pens with high stocking density had a 90% higher hazard of fouling compared to pens with low stocking density ($P=0.016$), meaning that pens with a high stocking density had a higher risk of fouling and of developing it earlier. Pens with straw provided had a 49%

higher hazard of fouling compared to pens with no straw provided ($P=0.14$). No interaction was seen between stocking density and straw provision ($P=0.80$). In conclusion, stocking density was a significant risk factor of fouling, whereas straw provision only indicated this numerically within the used experimental setup and chosen sample size. The results suggest that lowering the stocking density to a level of around 1.21 m²/pig could reduce the risk of fouling in slaughter pigs. The relationship between fouling and straw provision needs further investigation.

Keywords: Slaughter pigs, Fouling, Risk factors, Stocking density, Straw provision

Introduction

Fouling of slaughter pig pens happens when pigs change their excretory behaviour from occurring in the designated dunging area to the resting area. Conventional slaughter pigs are often housed in indoor pens with fully or partly slatted floors. The pens with partly slatted floor offer a solid lying area that is more comfortable to rest on and aims to encourage pigs to differentiate between the solid and slatted floor when resting and performing excretory behaviour. Pigs prefer to lie on the solid floor when not in heat stress (Aarnink et al., 1996), and the Danish legislation states that at least one third of the floor area should not be slatted (Ministry of Environment and Food of Denmark, 2017). Further, pens with solid flooring will decrease the manure surface and thereby the ammonia emission (Aarnink et al., 1996). It is considered both a welfare and environmental improvement to raise pigs on partly slatted floor; however, fouling is particularly a problem in pens with partly slatted floor. In addition, defecation on the solid floor area can result in a lower hygiene, bad air quality and higher ammonia emission, extra work for the farmer, disturbance of the pigs' resting behaviour and

an increase in agonistic interactions (Aarnink et al., 1996; Hillmann et al., 2004; Smulders et al., 2006). For all of the above reasons, it is important to prevent fouling. However, fouling is a multifactorial problem and thus prevention is not a straightforward task. One way to prevent fouling could be to remove known risk factors. We recently published a literature review on risk factors to fouling in conventionally housed slaughter pigs (Larsen et al., 2017b) and found that earlier studies indicate that to decrease stocking density could decrease the risk of fouling, whereas to provide straw in the designated resting area might have the opposite effect. However, to our knowledge, no earlier study has directly investigated the risk of fouling with these two factors included. The aim of the current study was to investigate whether high stocking density and straw provision are risk factors to fouling. The hypothesis was that both a higher stocking density and straw provision would increase the risk of fouling. Furthermore, a second aim was to investigate when fouling appears during the slaughter pig period.

Materials and methods

The present experiment was conducted from 2015 to 2016 in accordance with a protocol approved by the Danish Animal Experiments Inspectorate (Journal no. 2015-15-0201-00593). This study uses the same animals as Larsen et al. (2017a), and further details about the experimental setup can be found there.

Animals, housing and management

The experimental units were 112 pens with a total of 1624 slaughter pigs. The pens were divided between four batches (batch 1, 3 and 4: n=32 each; batch 2: n=16) running from June 2015 to November 2016. Two sections with 16 identical pens in each were used in the experiment (during batch 2, only one section was used). The pigs were inserted into their

respective slaughter pig pen at an average weight of 31.6 ± 6.6 kg. The pens were 13.52 m² in size with the floor divided between one third of slatted, drained and solid concrete floor. For both the slatted and drained floor, the gap between the slats was 2 cm. The slats were 8 cm in width for the slatted floor and 18 cm in width for the drained floor. Table 1 shows the temperature curve used (SKOV A/S, Roslev, DK). The climate in the sections was evaluated each morning and adjusted according to the needs of the pigs by a parallel shift of the temperature curve of 0.5 to 1.5 °C up or down. The stable staff adjusted the climate on section level if they saw pigs lying on the slatted floor before they entered the section (not possible later in the slaughter pig period, when pigs were taken up most of the space in the pen when lying down). Each pen included an automatically controlled sprinkler system (SKOV A/S, Roslev, DK) above the slatted floor. This was turned on the whole time during all rounds from 0800-2000 h except if the outdoor temperature fell below 5 °C. The system followed a linear curve going from 1% at a 0.5 °C increase from the temperature curve to 100% at a 4.0 °C increase. At 1%, the sprinklers were turned on with 45 minutes' intervals for 1 minute and at 100% with 20 minutes' intervals for 3 minutes. In the current study, the minimum was 14%.

Table 1 Temperature curve used for slaughter pigs as reference point for adjusting temperature in the slaughter pig section (SKOV A/S, Roslev, DK).

Day from insertion	1	7	14	21	28	35	42	64
Temperature in °C	21	20	19	18	18	18	17	17

Experimental design

The experiment had a 2 x 2 factorial design with the slaughter pig pens assigned to one level of each of two treatments: (1) stocking density of 0.73 m²/pig (high) v. 1.21 m²/pig (low,

STOCK), and (2) provision of straw v. no provision of straw (**STRAW**). Each level of each treatment was assigned to 16 pens in batch 1, 3 and 4 and to eight pens in batch 2. The assignment of the treatment STRAW was done in blocks of four pens for each level, and the two STOCK treatment levels were randomly assigned with two pens of each stocking density within each block. This random assignment of treatment to pens was performed independently for each batch. Slaughter pig pens with the high stocking density included 18 pigs and three feeding places, while slaughter pig pens with the low stocking density included 11 pigs and two feeding places. Pens provided with straw received 150 g of straw per pig per day on the solid floor. During batch 1, 2 and 3, the straw provided was long straw at a length of 8-10 cm, while during batch 4 half of the pens received long straw, while the other pens received chopped straw cut to a length of 3-4 cm. However, no difference was seen between the two straw length treatments in the number of first fouling events or in an average clotting score of the slats, and thus this factor was not included in the following statistical analysis.

Identification and definition of a fouling event

During the daily check-up performed by the herd staff from 1000 to 1200 h, a protocol for scoring diarrhoea, fouling and tail biting events was followed. A fouling event was defined to be when more than half of the solid floor was wet with excreta and/or urine.

Statistical analyses

In the following analysis, only the first event of fouling for each pen was included. Thus, results represent whether a pen had a fouling event or not and when it happened; not the total number of fouling events for a particular pen. All statistical analyses were performed in R (R Core Team, 2016) using the package 'survival' for survival analysis (Therneau, 2015). Data

were modelled by a Cox regression assuming proportional hazards. The survival object contained the information of whether a pen had a fouling event during the study period and which day during the study period the first fouling event occurred. Pens which did not develop a fouling event during the entire slaughter pig period were right censored. The model included the main effects STRAW, STOCK and the interaction between the two. The model further included stratification for batch number. The model was reduced according to a 5% significance level ($P<0.05$). The results are presented as frequency/incidence of first fouling event and differences are presented as hazard rate ratios (HRR) with connected 95% confidence intervals (CI).

A post hoc power analysis was performed using the 'powerSurvEpi' package in R (Qui et al., 2015) with an effect size (HRR) of 1.9 for STOCK and 1.49 for STRAW (based on results from the model described above) and sample size of both treatment and control group of 56. This resulted in a power of only 0.66 for STOCK and 0.40 for STRAW. The effect of STOCK and STRAW should have been 2.2 and 1.91, respectively, or a higher sample size should have been used to get a power above 0.80 usually seen as the minimum when designing animal studies (Charan and Kantharia, 2013).

Results

Incidence of fouling

Out of the 112 pens included, 59 pens developed at least one event of fouling during the slaughter pig period (53%). The number of pens with a first event of fouling within each week of the study period divided between the four batches can be seen in Table 2. Incidences divided between the two treatments STRAW and STOCK can be seen in Table 3.

Table 2 Frequency of first fouling event divided between the four batches and 10 weeks of study period.

Batch no.	Week number										Total
	1	2	3	4	5	6	7	8	9	10	
1	5	0	2	2	1	1	1	2	1	5	20
2	0	0	0	0	1	2	0	3	3	1	10
3	2	0	0	0	1	1	1	4	1	2	12
4	2	1	0	0	3	3	2	1	0	5	17
Total	9	1	2	2	6	7	4	10	5	13	59

Table 3 Frequency and incidence of first fouling event divided between the two treatments STRAW and STOCK and the combination of the two.

Treatment	Level	No. of pens	No. of first fouling event	Incidence (%)
STOCK	Low	56	25	44.64
	High	56	34	60.71
STRAW	No straw	56	26	46.43
	Straw	56	33	58.89
STOCK x STRAW	Low x No straw	28	9	32.14
	Low x Straw	28	14	50.00
	High x No straw	28	16	57.14
	High x Straw	28	20	71.43

Risk factors to fouling

No interaction was seen between the two treatments STRAW and STOCK ($P=0.80$). The hazard of fouling was 90% higher in pens with high stocking density compared to pens with low stocking density. The hazard of fouling was 49% higher when straw was provided compared

to when no straw was provided to the pen, although, this was not significant. Statistical results can be seen in Table 4 and the development of first fouling events for each treatment is illustrated in Figure 1.

Table 4 Results from the Cox regression presenting the hazard rate with connected 95% confidence intervals (CI) for each treatment level and the comparison of levels within treatment.

Treatment	Level	Hazard rate	95% CI	<i>P-value</i>
STOCK	Low	1.00		
	High	1.90	1.12-3.22	0.016
STRAW	No straw	1.00		
	Straw	1.49	0.75-2.50	0.14

Discussion

Incidence of fouling

We found that over half of the pens developed a fouling event. However, we only considered the first fouling event developed, and thus our result is an underestimate of the actual incidence of fouling. Instead, the results tell us how many pens that did not develop fouling during the entire slaughter pig period. Despite some variation between batches, most pens developed fouling for the first time right after insertion or during the last three weeks of the slaughter pig period. The latter fits with the hypothesis that stocking density affects fouling since stocking density probably has a larger effect in the end of the slaughter pig period due to pigs weighing more and taking up more floor space. When a smaller part of the floor is available for movement, the pigs might be restricted to stay where they are and thus forced to also perform their excretory behaviour in their current position. Further, a heavier pig also

has a higher heat production, which makes it more sensitive to high ambient temperatures (Hillmann et al., 2004), and increasing temperature has been related to fouling in multiple studies (Huynh et al., 2005; Aarnink et al., 2006; Savary et al., 2009; Spoolder et al., 2012). Pigs in heat stress might choose to lie on the cooler slatted floor (Savary et al., 2009) and then choose the solid floor as dunging area, resulting in fouling. Jensen et al. (2012) found the same pattern in the occurrence of fouling with a higher average percentage of the lying area contaminated, a higher percentage of pens needing manual cleaning and a higher percentage of pens with a 100% contamination on day 60 after insertion to the slaughter pig unit compared to day 10 after insertion. These results by Jensen et al. (2012) also suggest that the definition of a fouling event is important for the timing of fouling. We could have chosen both a less and more severe definition with less or more than half of the solid floor soiled which could have changed our results. We did not find an interaction between stocking density and straw provision and thus, the effects of lowered stocking density and straw provision are mutually independent, but still additive. The results do indicate this since combining high stocking density and straw provision gave us the highest incidence of fouling, whereas combining low stocking density and no straw provision gave us the lowest.

Effect of stocking density

We compared a stocking density of 0.73 m²/pig to a stocking density of 1.21 m² per pig. The hazard of first event of fouling was almost twice as high for pens with the high stocking density. This higher hazard represents both a higher relative risk of fouling, but also the fact that fouling was seen earlier in pens with the high stocking density, which is clearly seen by the early separation of the two graphs in Figure 1A. Thus, stocking density was a statistically significant risk factor of fouling in our study. Hillmann et al. (2005) compared similar stocking

densities of 0.7 m²/pig and 1.4 m²/pig and saw a tendency for pigs to spend more time lying in the dunging area at high stocking densities, which could be an indirect sign of fouling. Hacker et al. (1994) compared 0.64 m²/pig to 1.0 m²/pig and performed a dunging score three times per week throughout the slaughter pig period. They did not find a direct effect of stocking density on the average dunging score, but they did find that the higher stocking density enhanced the effect of other risk factors to fouling such as having open partitions in the pen. Jensen et al. (2012) studied the percentage of contamination of the lying area and did not reduce fouling when changing the stocking density from 0.67 m² per pig to 0.79 m²/pig. All three of the above studies also used pens with partly slatted floors. Thus, a decreased stocking density might first be able to reduce the risk of fouling at a lower level such as the one used in the our study of 1.21 m²/pig or even lower as the one used by Hillmann et al. (2005) of 1.4 m²/pig.

The effect of straw provision

The results showed that provision of 150 g of straw per pig per day on the solid floor was not a statistical significant risk factor of first event of fouling in our study although the numerical result went in that direction. However, the size of the experiment combined with the found effect size of straw did only provide a power of 0.41 and thus, we might have missed an effect of straw provision that is actually existing and which could have appeared with a higher sample size. Although, Figure 1B shows that the two graphs overlap during the slaughter pig period and thus, a higher sample size might not have made a difference. Figure 1B also illustrates, that we might find a higher relative risk of fouling in pens with straw late in the slaughter pig period, while pens without straw seemed to have a relative higher risk of fouling early in the period. This was not seen for stocking density where pens with the higher stocking density

seem to both have a higher relative risk of fouling and develop fouling earlier. Thus, whether we see an effect of straw and whether it is negative or positive when considering the risk of fouling may depend on the timing of the fouling event. The higher incidence of fouling early after insertion in pens without straw indicates that straw provided on the solid floor may help pigs to differentiate the resting area from the dunging area, maybe due to the straw covered floor being more comfortable to rest on than a bare concrete, both from a point of view of thermal comfort and a softer surface. However, as pigs grow with age, all pigs cannot fit into the lying area, and thus some pigs are forced to rest in other parts of the pen and may thus be more likely to foul on the solid floor. This will result in dirty straw and may cause more severe fouling than without straw. We have only been able to locate two studies that have investigated the relationship between straw provision and fouling (Spooler et al., 2000; Savary et al., 2009). Spooler et al. (2000) found that a smaller proportion of the floor was soiled in pens with around 300 g of straw per pig per day compared to pens with bare concrete; however the straw was provided in a straw hopper and not directly on the floor. Savary et al. (2009) provided 100 g of straw per pig per day, or none, and found a stronger association between a four-level fouling score of the solid floor and increased room temperature when straw was provided. Savary et al. (2009) did not see a direct effect of straw provision, but instead an interaction between room temperature and straw provision. This suggests that straw on the solid floor might cause heat loss problems getting the pigs to choose the dunging area as their new resting area, causing fouling. Thus, straw provision might only be a risk factor of fouling at high temperatures. This supports the above discussion that a negative relationship between fouling and straw was only seen towards the end of the slaughter pig period where the pigs are more sensitive to high temperatures (Hillmann et al., 2004). We might have seen the same effect in our study if room temperature had been

included. However, we did see the highest incidence of first fouling event in batch 1, which was the only batch performed during summer from June to August. Further, the results by Savary et al. (2009) state the importance of keeping the correct climate when trying to prevent fouling also when using other measures. Also, temperature measurements of the straw-bedded area might also prove effective in predicting events of fouling, which has already been shown for temperature measurements at other locations of the pen (Jensen and Kristensen, 2016). Straw has been shown to have other positive effects for slaughter pigs such as reducing the risk of tail biting (Van de Weerd et al., 2005; Scollo et al., 2013; Larsen et al., 2017a) and gastric ulceration (Di Martino et al., 2013; Herskin et al., 2016; Jensen et al., 2017), improving growth rate (Pedersen et al., 2015) and increasing the expression of species-specific behaviour such as exploration (Jensen et al., 2015). Thus, it is desirable to be able to provide straw or enrichment with similar properties without increasing the risk of fouling, and, according to our study, provision of straw was not a major risk factor. However, due to limited number of studies on this subject and the fact that the three studies do not show similar results, there is a need for future research into the relationship between fouling and straw provision.

Conclusion

In the current study, fouling appeared for the first time mostly right after insertion to the slaughter pig section and in the end of the slaughter pig period. Stocking density was a significant risk factor to fouling while straw provision was not a significant risk factor. More pens with high stocking density developed fouling, and they developed it earlier compared to pens with low stocking density. The results suggest that lowering the stocking density to a level of 1.21 m²/pig could reduce the risk of fouling in slaughter pigs kept in pens with partly

269 slatted floors while the relationship between fouling, thermal comfort and straw provision
270 needs further investigation.

271

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352

Figure captions

Figure 1 Cumulative incidence plots of first fouling event divided between (A) pens with high (n=56) and low stocking density (n=56), (B) pens without straw (n=56) and with straw (n=56). Each smallest jump in the graphs indicates an event of first fouling, as shown by the arrows.