frontiers | Frontiers in Animal Science

TYPE Original Research
PUBLISHED 03 April 2024
DOI 10.3389/fanim.2024.1331723

OPEN ACCESS

EDITED BY
Paul Lelovas,
National and Kapodistrian University of Athens, Greece

REVIEWED BY
Nina Volkmann,
University of Veterinary Medicine Hannover, Germany
Isabel Hennig-Pauka,
University of Veterinary Medicine Hannover, Germany

*CORRESPONDENCE
Ulrike Höne
ulrike.hoene@fli.de

RECEIVED 01 November 2023
ACCEPTED 15 March 2024
PUBLISHED 03 April 2024

CITATION
Höne U, Schrader L, Hölscher R, Traulsen I and Krause ET (2024) Measures to affect the elimination behaviour of fattening pigs in a conventional housing system.
Front. Anim. Sci. 5:1331723.
doi: 10.3389/fanim.2024.1331723

Measures to affect the elimination behaviour of fattening pigs in a conventional housing system

Ulrike Höne[1]*, Lars Schrader[1], Richard Hölscher[2], Imke Traulsen[3] and E. Tobias Krause[1]

[1]Institute of Animal Welfare and Animal Husbandry, Friedrich-Loeffler-Institute, Celle, Germany, [2]Hölscher + Leuschner GmbH & Co. KG, Emsbüren, Germany, [3]Institute of Animal Breeding and Husbandry, Christian-Albrechts-University Kiel, Kiel, Germany

Pigs try to separate their lying area from the dunging area. However, due to several factors such as pen design, increasing ambient temperatures, or lack of space, pigs often lie in the dunging area or defaecate in the lying area, resulting in increased pen and animal soiling. Besides poor hygienic conditions, this may also lead to increased ammonia emissions. Thus, proper changes to support the structure of conventional pens may help facilitate better elimination behaviour of pigs and establish and maintain their functional areas, including dunging areas. In this study, we investigated the effect of measures to help pigs use pre-defined functional areas. The study was done on a conventional farm in pens with fully slatted floors. Pen and animal soiling was recorded by a scoring scheme in a total of 37 pens during two fattening periods. In the first fattening period (baseline period), the pen design remained unchanged to evaluate the status quo. In the second fattening period (treatment period), certain changes in 16 test pens were done to structure the pen into a designated dunging and a resting area. The remaining 21 pens served as control pens. Changes included installation of LED spotlights, partly open pen partitions, and re-arrangement of nipple drinkers and hay racks. To compare the soiling of pens, the difference in pen soiling was calculated both between the baseline and the treatment periods and the control and test pens. As a first step, the difference in pen soiling between the control and test pens within both fattening periods was compared. Additionally, to control for changes in pen soiling over time, the differences between the pen soiling of the control pens during the baseline period and the treatment period were compared. The same comparison was done for the test pens. In the treatment period, no significant difference in the pen soiling between the control pens and test pens was found. However, over time, i.e., comparing the soiling of test pens and control pens between the baseline and the treatment periods, pigs soiled the designated dunging areas more in the treatment period. The fattening pigs in both the test and the control pens were very clean during both fattening periods. Our pen modification treatment that combined changes in LED spotlights, drinker locations, roughage locations, and partly open pen partitions did not result in clear effects. However, we can not rule out that these features can help to structure the pens in a positive way.

KEYWORDS

fattening pigs, conventional pig housing, pen design, elimination area, pen soiling

1 Introduction

Areas used by fattening pigs for elimination are often wet, cool, and illuminated places that are located in corners, allowing pigs to have access to neighbouring pens by having partly open pen partitions (Van Putten, 1978; Zerboni and Grauvogl, 1984). In contrast, their resting areas are comfortable, dry, and thermoneutral (Geers et al., 1990). Pigs avoid eliminating, i.e., urinating and defaecating, in the resting area, indicating that the pig's main priority is to choose a suitable lying area and use an area not preferred for resting for elimination (Baldwin, 1969; Buchenauer et al., 1982).

Nevertheless, a variety of factors have been described that affect the location of elimination behaviour of fattening pigs in conventional housing systems, e.g., stocking density, pen design, or increasing temperatures, which often influence the pens' and the animals' cleanliness and can lead to increased animal and pen soiling (e.g., Hacker et al., 1994; Ocepek and Andersen, 2022). This often results in poorer animal and pen hygiene as well as an increased amount of ammonia emissions (Philippe et al., 2011; Larsen et al., 2018).

Stocking density is one important factor for pen and animal soiling in conventional-housed pigs. If available space is not sufficient (per pig), pigs often start lying in the dunging area (Larsen et al., 2017), and thus, animal soiling increases. Therefore, the proportion of the lying area should enable all pigs to lie simultaneously (Ekkel et al., 2003). Besides having sufficient available space in the lying area, Ocepek and Andersen (2022) found out that pen soiling can be reduced by sufficient available space for dunging. A dunging area of more than 0.41 m^2 per pig makes it possible for pigs to eliminate simultaneously (Ocepek and Andersen, 2022). In organic fattening pigs with access to outdoor runs and therefore more space available, the pigs defaecated significantly more often in the outdoor runs, and as such, there were no faeces inside (Höne et al., 2023). Another important factor is the openness of the pen surrounding and the resulting microclimate. Ocepek and Andersen (2022) found that the cleanest pens are those whose dunging areas were at the back of the pens where windows were located. This suggested that external climate effects such as sun exposure or cold draught by the window affect the choice of dunging area. In addition, open pen partitions in the dunging area can further support this choice due to draught (Hacker et al., 1994; Ocepek and Andersen, 2022). In some studies, a correlation or connection has been suggested between elimination behaviour at open pen partitions and territorial behaviour. Eliminating at open pen partitions may mark the territory, and therefore, pigs locate dunging areas close to the neighbouring pen at open pen partitions (Buchenauer et al., 1982; Zerboni and Grauvogl, 1984; Van Putten, 1978).

The illumination of the dunging area also seems to be crucial for choosing a dunging area (Zerboni and Grauvogl, 1984). Pigs tend to rest in darker areas while using brighter illuminated areas for elimination (Van Putten, 1978). Because pigs avoid eliminating near the feeding areas (Nannoni et al., 2020), the location of the roughage supply may also affect the choice of dunging area.

Particularly during the summer months, pigs often lie in the dunging area (Hillmann et al., 2005). Due to their very few sweat glands, pigs need to perform specific behaviours for thermoregulation at high temperatures to achieve heat loss, e.g., by lying on slatted rather than on solid floors (e.g., Hillmann et al., 2005; Huynh et al., 2005; Savary et al., 2009), by avoiding physical contact to pen mates or by wallowing in the dunging area (Olczak et al., 2015). Hillmann et al. (2005) described increased lying in dunging areas at temperatures above 25°C and suggested additional cooling systems to avoid pen and animal soiling.

In this study, we investigated the pen and animal soiling of fattening pigs over two fattening periods (baseline and treatment) on a conventional pig farm. If these changes in the pens' structure enable us to manage and control dunging areas, they can represent good practicable tools for farmers to structure even pens with fully slatted floors and to maintain pens and keep animals clean, possibly resulting in lower emissions.

2 Materials and methods

The study was conducted between March 2021 and February 2022 on a conventional fattening pig farm in Lower Saxony, Germany. Throughout two fattening periods (baseline period and treatment period), 37 pens and a total of 345 fattening pigs were observed, respectively. The pigs were housed according to the German legislation, i.e., the "Tierschutz-Nutztierhaltungsverordnung" (TierSchNutztV, 2021). All pens were equipped with concrete slatted floors, nipple drinkers, and enrichment materials. Moreover, the farm participated in the German "*Initiative Tierwohl*" (https://initiative-tierwohl.de/en/), a private sector initiative aiming to improve the welfare of farm animals. By that, certain requirements that go beyond the minimal requirements of the legislation had to be fulfilled such as 10% additional space (i.e., 0.825 m^2 per pig instead of 0.75 m^2) and provision of additional roughage, i.e., by hay racks. Pairs of pens were supplied with feed by one trough at an animal:feeding place ratio of 1:1. Pigs were fed with liquid feed (Hoelscher + Leuschner GmbH and Co. KG, Emsbüren, Germany) four times per day. Supply air advected through a perforated ceiling and was discharged by exhaust air chimneys.

The respective weather data for the two fattening periods were retrieved by the Deutscher Wetterdienst Climate Data Center (DWD Climate Data Center CDC, 2023; https://opendata.dwd.de/). The selected weather station was in Groß Berßen, Lower Saxony (N 52.7553, E 7.4815). The linear distance to the stable is 41.82 km. The average temperature during the first fattening period (baseline period) was 6.6°C. In February, the average temperature was 3.0°C, 6.0°C in March, 6.5°C in April, and 11.8°C in May. In the second fattening period (treatment period), the average temperature was 5.6°C. In November, the average temperature was 6.7°C, 4.0°C in December, 4.8°C in January, and 5.9°C in February. Weather data were also recorded in the barn but only for the treatment period due to a computer system failure in the baseline period. The average temperature in the compartment during the treatment period was 22.9°C in November, 21.8°C in December, 20.4°C in January, and 18.9°C in February. In both periods, the temperature curve of the climate computer started with a target temperature of 25°C and then declined to 17°C by the end of the fattening period.

2.1 Animals

On the farm, in each of the two fattening periods (baseline and treatment), we examined 345 fattening pigs kept in 37 pens in an 'all-in and all-out' procedure, respectively. The number of pigs per pen ranged from 7 to 12 pigs per pen, depending on the pen size (Supplementary Figure S1). Sixteen pens were used as test pens and 21 pens as control pens (Supplementary Figure S1). In the baseline period, the housed pigs were crossbreeds of the genetic sow (Yorkshire × Landrace) × Piétrain (PIC 408). The pigs were transferred to the pens at an average body weight of 32.0 kg. In the test period, crossbreeds' products of Bundeshybridzuchtprogramm (BHZP; German Federal Hybrid Breeding Program) × Piétrain (PIC 408) were transferred to the pens with an average weight of 30.4 kg. The male pigs were castrated, and tails of all pigs were docked.

2.2 Study design

To investigate the soiling of pens and animals, the soiled area of each pen and the soiling of each pig were visually assessed five times per fattening period (the time point of pen-soiling assessment). In the baseline period, the aim was to record the status quo of pen and animal soiling. We expected that pigs in the pens located at the outer wall of the barn will soil the pen area adjacent to the outer wall. This was confirmed in the baseline period. To test whether fattening pigs use predefined dunging areas, an alternating experimental design was used. In the treatment period, we established designated dunging areas by modifying 16 test pens, located at the outer wall (Figure 1, Supplementary Figure S1).

The study was conducted in a two-stage experimental design, i.e., consisting of two periods: (i) In the baseline period, control pens (n=21) were compared with the prospective, but still unmodified test pens (n=16) (Figure 1). (ii) In the treatment period, the control pens were compared with the modified test pens (Figure 1). For the assessment of soiling, all pens were divided in advance into three areas, from A to C, alternately in pairs (Figure 2). This designation was applied to all 37 pens in the same alternating series to compare the baseline and treatment periods.

In the treatment period, the test pens were rebuilt alternately in pairs. The predefined dunging areas were located either at the outer wall or at the opposite side, i.e., at the barn alley.

2.3 Pen design

In the baseline period, the pen design remained unchanged, i.e., as it was previously in that conventional barn to record the status quo. All pens were equipped with a hay rack at the control alley, a nipple drinker in the back of the pen, and open pen partitions (Figure 2).

In the treatment period, the pen design of 16 test pens, which were located at the outer walls of the barns were modified. All changes of the pen structure done to predefine functional areas were carried out alternately in pairs of pens, i.e., in two pens that were located between the troughs for liquid feeding (Figure 2). To predefine the dunging area, the open pen partitions were closed except for the last third at the outer wall or the first third at the control alley, respectively (Figure 2). In addition, above the predefined dunging areas, LED spotlights (Ledino, 10 W, at least 800 lm, CRI > 80 Ra, warm white 3000 K) were installed at the ceiling at the level of 2.51 m above ground. Nipple drinkers were installed in the predefined dunging areas (i.e., at the open pen partitions with additional LED spotlights), and the hay racks were installed at the opposite side (Figure 2).

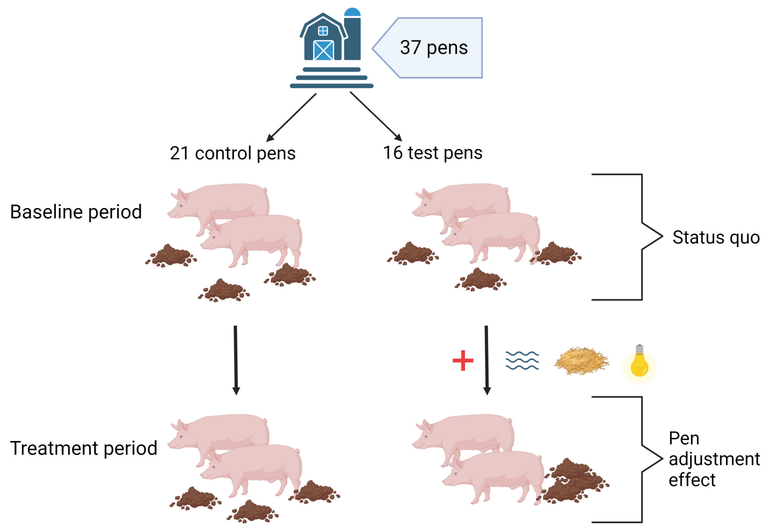

FIGURE 1
Schematic drawing of the experimental design. Wave pictograms indicate the nipple drinkers; rectangle pictograms indicate the hay racks; lightbulb pictograms indicate the LED spotlights; and dung pictograms indicate pen soiling. [Created with BioRender.com].

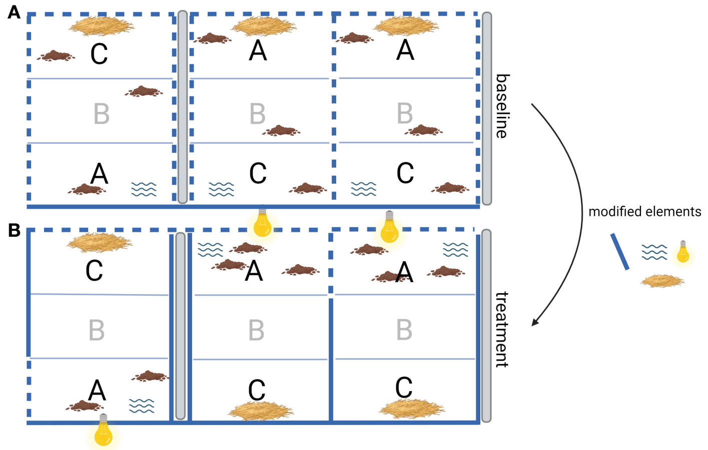

FIGURE 2
Schematic drawing of the experimental design: **(A)** exemplary pens of the baseline period and **(B)** exemplary pens of the treatment period with the respective treatments. A to C = assessed areas, designation of all 37 pens, alternately in pairs (Two pens located between the liquid feeding were regarded as a pair, respectively). Wave pictograms indicate the nipple drinkers; straw pictograms indicate the hay racks; lightbulb pictograms indicate the additional LED spotlights; and dung pictograms indicate pen soiling. Dashed lines indicate visually open pen partitions; solid lines indicate closed pen partitions; and grey areas indicate the troughs for liquid feeding. [Created with BioRender.com].

2.4 Assessment of pen and animal soiling

The first assessment of the baseline period was performed 29 days after transferring the pigs to the pens. The second assessment was performed 3 weeks later and the third to fifth assessments were performed every 2 weeks. In the treatment period, the first assessment was performed 21 days after transferring and the second assessment, 28 days later. Again, the third to fifth assessments were performed every 2 weeks.

The pen and animal assessments were always conducted by one observer (U.H.). For the assessment of pen soiling, each pen was virtually divided into 3*2 (=6) equal areas, which were assessed separately in order to obtain a fine graded assessment (e.g., to be able to analyse if certain corners of the pens were soiled). The evaluation of soiled area was conducted according to Opderbeck et al. (2020), using a scale from 0 to 4. A score of 0 indicated a soiled area of 0% to 10%; a score of 1 indicated a soiled area of 10% to 25%; a score of 2 indicated a soiled area of 25% to 50%; a score of 3 indicated a soiled area of 50% to 75%; and a score of 4 indicated a soiled area greater than 75% to 100%. Two of the six areas assessed were always adjacent to each other and were summed up, leaving three areas (A, B, and C) for further analysis (Figure 2). The sum of each area (A, B, and C) of each pen in each assessment could range from 0 to 8, in accordance with the scoring system. Area B was not entered into the equation, due to only minor or no soiling in this area.

The assessments of the animal soiling were conducted following Schrader et al. (2016). One side of each pig was assessed by using scores from 0 to 2. A score of '0' indicated that less than 10% of the side of the pig was soiled. A score of '1' indicated that 10% to 30% of the side of the pig was soiled. A score of '2' indicated that >30% of the side of the pig was soiled.

2.5 Data preparation: pen soiling

In the test pens of the treatment period, the designated dunging area, i.e., the area with the LED spotlights, the nipple drinker, and the open pen partition was assigned to area A. The opposite area was assigned to area C, i.e., the designated resting area with the hay rack (Figure 2).

By assigning the floor of each pen in both fattening periods to the same area A or C, the change in the soiled areas could subsequently be calculated. The difference of area A minus area C within each pen was calculated to determine the change of soiled areas within each pen. The calculated difference attained values between 8 and –8. If the difference is positive, it indicated that the pigs soiled area "A", the designated dunging area, more than area "C". A negative difference indicated a soiling of area "C" than of "A".

2.6 Ethical statement

Pigs were not isolated from conspecifics nor restricted from any resources and remained in their familiar environment throughout the study. The housing conditions and animal care were accomplished in accordance with German legislation for pig production (TierSchNutztV, 2021). The fattening pigs from the study were marketed after the study.

2.7 Statistical analyses

The statistical analyses were performed in R studio version 4.1.1 (RStudio Team, 2022) with the package "nlme" (Pinheiro et al., 2023).

To analyse the difference in pen soiling, we compared the soiling of control pens and test pens within each fattening period (i.e., baseline and treatment) [Supplementary Figure S2, linear mixed models (LMEs) 1 and 2]. To test for changes between periods, we compared the soiling of control pens between the baseline and treatment periods (Supplementary Figure S2, LME 3). In addition, we tested for changes in soiling between the prospective test pens in the baseline period and the test pens in the treatment period (Supplementary Figure S2, LME 4).

LME 1 – hypothesis: There is no difference in pen soiling between the control pens and test pens in the baseline period. The fattening pigs soil the whole pen.

LME 2 – hypothesis: The difference in pen soiling varies between the control pens and test pens in the treatment period. The fattening pigs in the test pens soil the designated dunging areas.

LME 3 – hypothesis: There is no difference in pen soiling between the baseline und treatment periods in the control pens. The fattening pigs soil the whole pen.

LME 4 – hypothesis: There is a difference in pen soiling between the baseline und treatment periods in the test pens. The fattening pigs in the treatment period soil the designated dunging areas.

We used four separate linear mixed models (LMEs) (Supplementary Figure S2) because the explanatory factor (i.e., prospective treatment *vs.* treatment) was substantially different from the baseline period to the treatment period.

In LME 1 (Supplementary Figure S2), we included only data from the baseline period and compared the 21 control pens with the 16 prospective test pens, in order to test for differences in pen soiling in the baseline period, i.e., before changing the pen design. The explanatory variables were the prospective treatment (two-level factor: 16 prospective test pens, 21 control pens), the time point of pen-soiling assessment (five-level factor: measures 1, 2, 3, 4, and 5), their two-way interactions, and the number of pigs per pen. For nesting random factor, penID was considered.

In LME 2 (Supplementary Figure S2), all pens of the treatment period were analysed. The explanatory variables were the treatment (two-level factor: 16 test pens, 21 control pens), the time point of pen-soiling assessment (five-level factor: measures 1, 2, 3, 4, and 5), their two-way interactions, and the number of pigs per pen. Again, for nesting random factor, penID was considered.

To consider the effect over time, we analysed the difference in soiling between the baseline period and the treatment period for the control pens and the test pens, respectively (LMEs 3, 4).Thus, in LME 3 (Supplementary Figure S2), the differences between the control pens of both fattening periods were analysed with these explanatory variables: the fattening period (two-level factor: baseline period, treatment period), the time point of pen-soiling assessment (five-level factor: measures 1, 2, 3, 4, and 5), their two-way interactions, and the number of pigs per pen, with penID as the nesting random factor.

In LME 4 (Supplementary Figure S2), the difference between the test pens of both fattening periods were analysed. The explanatory variables were the fattening period (two-level factor: baseline period, treatment period), the time point of pen-soiling assessment (five-level factor; measures 1, 2, 3, 4, and 5), their two-way interactions, and the number of animals in each pen. The nesting random factor was the penID.

Animal soiling was only analysed by descriptive statistics due to lack of variation, i.e., almost none of the animals showed any soiling.

3 Results

In total, 2,220 pen-soiling assessments were recorded: 5.23% of the areas were assessed with a score of 4, 7.39% with a score of 3, 12.39% with a score of 2, 11.44% with a score of 1, and 63.65% with a score of 0. In the baseline period, 55 areas were assessed with a score of 4 (4.96%), 89 areas with a score of 3 (8.02%), 130 areas with a score of 2 (11.71%), 134 areas with a score of 1 (12.07%), and 704 areas with a score of 0 (63.42%). In the treatment period, 61 areas were assessed with a score of 4 (5.5%), 75 areas with a score of 3 (6.76%), 145 areas with a score of 2 (13.1%), 120 areas with a score of 1 (10.8%), and 709 areas with a score of 0 (63.9%).

There was no difference in pen soiling in the baseline period (LME 1) between the control and the prospective test pens (LME, $F_{1, 34} = 0.01$, $P = 0.94$; Figure 3). Neither the time point of pen-soiling assessment nor its interaction with the type of pens affected the difference in pen soiling (LME, the time point of pen-soiling assessment $F_{4, 140} = 0.43$, $P = 0.78$; prospective treatment* the time point of pen-soiling assessment $F_{4, 140} = 0.08$, $P = 0.99$). Also, the number of pigs per pen did not affect the difference in pen soiling (LME, $F_{1, 34} = 0.31$, $P = 0.57$).

In the LME 2, pen soiling did not differ between the control and the test pens in the treatment period (LME, $F_{1, 34} = 1.88$, $P = 0.18$; Figure 3). Neither the interactions of treatment and the time point of pen-soiling assessment nor the number of pigs per pen affected the difference in pen soiling (LME, treatment* the time point of pen-soiling assessment $F_{4, 140} = 1.23$, $P = 0.30$; number of pigs per pen $F_{1, 34} = 0.50$, $P = 0.48$). However, the difference in pen soiling in the treatment period (LME 2) was affected by the time point of pen-soiling assessment (LME, the time point of pen-soiling assessment $F_{4, 140} = 2.65$, $P = 0.04$). The difference in pen soiling was lower in the fourth assessment than in the other four assessments.

Soiling of control pens differed between the two fattening periods (LME 3, $F_{1, 180} = 10.05$, $P = 0.002$; Figure 4). Also, the soiling of the (prospective) test pens differed between both periods (LME 4, $F_{1, 180} = 32.88$, $P < 0.001$; Figure 4). In the treatment period, pigs soiled the designated dunging areas of the test pens more often compared to the baseline period. Also, the pigs in the control pens soiled the assigned area A more often in the treatment period.

In both models (LME 3, 4), the time point of pen-soiling assessment and the interactions did not affect the difference in soiling (LME 3, the time point of pen-soiling assessment $F_{4, 180} = 1.08$, $P = 0.37$; time control* the time point of pen-soiling assessment $F_{4, 180} = 0.63$, $P = 0.64$; LME 4, the time point of pen-soiling assessment $F_{4, 135} = 0.21$, $P = 0.93$; treatment* the time point of pen-soiling assessment $F_{4, 135} = 0.51$, $P = 0.73$). Also, the difference in pen soiling was not affected by the number of pigs per pen (LME 3, $F_{1, 19} = 0.08$, $P = 0.78$; LME 4, $F_{1, 14} = 2.44$, $P = 0.14$).

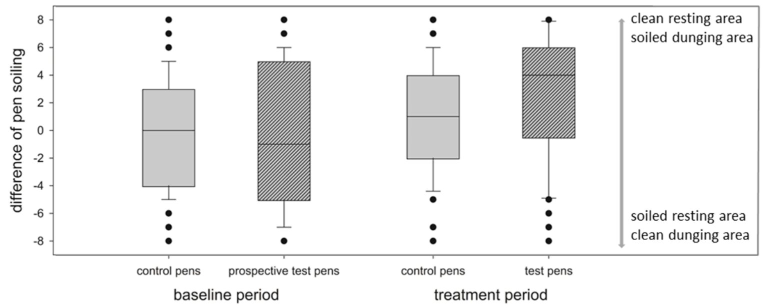

FIGURE 3
Differences in pen soiling (area A − area C) between control pens and test pens in the baseline and treatment periods. Baseline period = grey boxes and treatment period = striped boxes (LMEs 1 and 2). Positive difference = soiling of designated dunging area and negative difference = soiling of designated resting area. The horizontal lines in the boxes represent the median, while the boxes and whiskers describe the quartiles.

In total, 3,346 animal-soiling assessments were recorded: 3.43% of the pigs were assessed with a score of 1 and 1.26% of the pigs were assessed with a score of 2. Thus, 95.31% were assessed with a score of 0. In both periods, the fattening pigs were very clean; however, soiled animals were assessed more often in the baseline period as in the treatment period. In the baseline period, 90 pigs were assessed with a score of 1 (5.28%) and 32 pigs were assessed with a score of 2 (1.88%), while in the treatment period, only 25 pigs were assessed with a score of 1 (1.52%) and 10 pigs with a score of 2 (0.61%). The remaining animals were assessed with a score of 0.

4 Discussion

The aim of this study was to influence the dunging behaviour of fattening pigs by pre-defining a dunging area based on pen specific treatments. The modifications were done; however, the outcome did not result in clear effects on pen cleanliness.

As expected, prospective test pens and control pens did not differ in soiling in the baseline period. However, also in the treatment period, test and control pens did not differ significantly in soiling. Unexpectedly, the designated dunging areas, i.e., area A of both test and control pens, were more soiled over time, based on the comparison of the results for the test and control pens in the baseline and treatment periods. This result shows the use of the designated dunging areas by the fattening pigs. The modifications of the test pens were carried out alternately in pairs, with the designated dunging area at the outer wall or at the opposite side, the control alley. The locations of the dunging areas could be changed by the modifications in the test pens, resulting in the usage of dunging areas both at the outer walls and at the opposite side. Regarding possible effects, Ocepek and Andersen (2022) described increased pen cleanliness in pens with partly open pen partitions. One reason might be the air draught as pigs prefer dry and thermoneutral areas for lying (Geers et al., 1990) and conversely, used the cooler areas for elimination (Hacker et al., 1994; Ocepek and Andersen, 2022). Further evaluations concerning the impact of air draught were not possible yet, as we did not measure air velocities in our study. Another influence might be the territorial behaviour of the fattening pigs, which can be related to the elimination behaviour at open pen partitions. It had been suggested that pigs tend to eliminate at the territorial boundary to mark their territory, and thus, open pen partitions result in more dunging areas at the open areas (Van Putten, 1978; Zerboni and Grauvogl, 1984). However, this behaviour pattern has not been confirmed yet (Hacker et al., 1994; Andersen et al., 2020). In our study, the pigs in the control pens also soiled, significantly more often, area A than area C in the treatment period. We did not expect

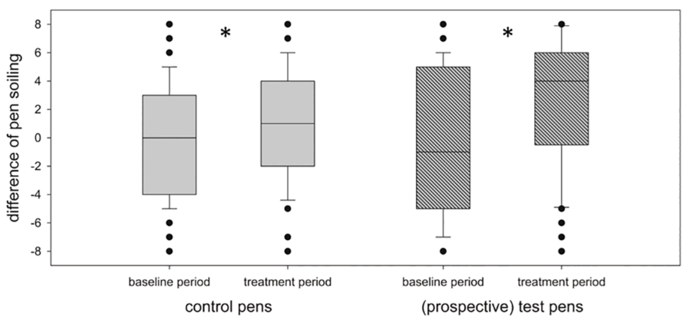

FIGURE 4
Differences in pen soiling of the control (grey boxplots) and the test (striped boxplots) pens in the baseline and the treatment periods (LMEs 3 and 4). Positive difference = soiling of designated dunging area and negative difference = soiling of designated resting area. The horizontal lines in the boxes represent the median, while the boxes and whiskers describe the quartiles. Asterisks indicate significant differences.

this result and cannot explain why the pigs in the control pens have shifted their dunging areas. Although the pen partitions of the control pens were completely open, the pigs soiled a particular area in the pen which at least does not support the abovementioned idea of dunging areas being involved in territorial behaviour. Nevertheless, regardless of the exact underlying mechanism, our results confirm that pigs create functional areas, in line with earlier studies (e.g., Baldwin, 1969; Zerboni and Grauvogl, 1984). However, the shifting of the dunging areas may have been a coincidence and require further investigations.

Due to the use of spotlights in slatted areas, Opderbeck et al. (2020) described more pigs lying on solid, not illuminated, areas. However, the use of spotlights had no significant effect on soiling in the lying areas (Opderbeck et al., 2020). In our study, pigs housed in the test pens, soiled the illuminated areas significantly more over time. Nevertheless, it could have been a coincidence, since the treatment had no significant effect on the difference in soiling comparing the control and test pens within the treatment period. However, Götz et al. (2022) described more soiling in illuminated areas than in almost completely darkened pen areas. This assumption is in line with another study in which growing pigs were investigated in preference test rooms. Pigs preferred to lie down in the darkened area and eliminated in the illuminated areas (Taylor et al., 2006).

In addition to structural elements of pens, the stocking density is mentioned as an influencing factor that increases pen and animal soiling (Larsen et al., 2017, 2019). Sufficient available space allows fattening pigs in a pen to perform different behaviour patterns, e.g., lying or eliminating simultaneously without automatically disturbing pen mates. Ocepek and Andersen (2022) pointed out that pigs need to be able to move unrestrictedly in pens in order to establish functional areas and to maintain them. However, Jensen et al. (2012) on the other hand, found no such effects when they investigated pen hygiene at different stocking densities (0.67 m^2, 0.73 m^2, and 0.79 m^2 per pig). Likewise, in our study, the difference in soiling was not affected by the number of pigs per pen.

Pen soiling is often seen in pens with partly slatted floors (e.g., Rantzer and Svendsen, 2001; Larsen et al., 2017), related to increasing temperatures (e.g., Aarnink et al., 1997; Hillmann et al., 2004; Huynh et al., 2005; Aarnink et al., 2006). Although Spoolder et al. (2012) described that pen hygiene was not affected by the stocking density, they indicated that space requirement is affected by increasing temperatures (e.g., as temperatures increase, pigs require more space to avoid physical contact with other pigs when lying). Exceeding the thermoneutral temperature of fattening pigs, a coping behaviour like wallowing, avoiding contact with other pen mates, or lying on the slatted area, to cool themselves down, have been described (e.g., Hillmann et al., 2005; Huynh et al., 2005; Aarnink et al., 2006). In our study, investigations were done during the cooler months. The baseline period was performed from February to May (mostly spring) and the treatment period from November to February (winter). The average outdoor temperatures during the periods were 6.6°C and 5.6°C. These low outdoor temperatures might be one reason for less animal and pen soiling because temperatures stay within the thermoneutral range of fattening pigs (Hillmann et al., 2004). In our study, these temperatures have probably not been exceeded. It would be interesting to investigate further fattening periods across seasons in terms of increasing temperature and the coping behaviour of fattening pigs. Also, investigations of certain treatments, especially the open pen partitions, might be interesting, to find out possible influences on the dunging behaviour of fattening pigs. Here, a detailed measurement of potential air draughts would be interesting. Additionally, the results of the use of different treatments might be helpful to structure outdoor runs of fattening pigs.

5 Conclusion

Our pen modification treatment that combined changes in light, drinker locations, roughage location, and partly open pen partitions did not result in clear effects on pen and animal cleanliness. This does not necessarily mean that these features do not help to structure the pens in a positive way, but the exact settings need to be investigated in future studies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because pigs were not isolated from conspecifics nor restricted from any resources and remained in their familiar environment throughout the study. The housing conditions and the animal care were accomplished in accordance to German legislation for pig production (TierSchNutztV, 2021). Additionally, the farm participated in the German branch solution "Initiative Tierwohl" (ITW Initiative Tierwohl, 2023). The fattening pigs from the study were marketed after the study.

Author contributions

UH: Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Visualization. LS: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing, Funding acquisition. RH: Writing – review & editing, Funding acquisition, Resources. IT: Writing – review & editing, Supervision. EK: Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing, Conceptualization, Visualization.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The project was supported by funds of the German Government's Special Purpose Fund held at Landwirtschaftliche Rentenbank (859352).

Acknowledgments

We would like to thank Andreas Klünter and the staff from Hölscher + Leuschner.

Conflict of interest

Author RH was employed by the company Hölscher + Leuschner GmbH & Co. KG.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fanim.2024.1331723/full#supplementary-material

References

Aarnink, A. J. A., Schrama, J. W., Heetkamp, M. J. W., Stefanowska, J., and Huynh, T. T. T. (2006). Temperature and body weight affect fouling of pig pens. *J. Anim. Sci.* 84, 2224–2231. doi: 10.2527/jas.2005-521

Aarnink, A. J. A., Swierstra, D., van den Berg, A. J., and Speelman, L. (1997). Effect of type of slatted floor and degree of fouling of solid floor on ammonia emission rates from fattening piggeries. *J. Agric. Eng. Res.* 66, 93–102. doi: 10.1006/jaer.1996.0121

Andersen, H. M.-L., Kongsted, A. G., and Jakobsen, M. (2020). Pig elimination behavior—A review. *Appl. Anim. Behav. Sci.* 222, 104888. doi: 10.1016/j.applanim.2019.104888

Baldwin, B. A. (1969). The study of behaviour in pigs. *Br. Vet. J.* 125, 281–288. doi: 10.1016/S0007-1935(17)48911-1

Buchenauer, D., Luft, C., and Grauvogl, A. (1982). Investigations on the eliminative behaviour of piglets. *Appl. Anim. Ethol.* 9, 153–164. doi: 10.1016/0304-3762(82)90191-2

DWD Climate Data Center CDC. (2023). Monatsmittel der Stationsmessungen der Lufttemperatur in 2 m Höhe in °C für Deutschland, Version v21.3. Available at: https://cdc.dwd.de/portal/202209231028/mapview (Accessed March 15, 2023).

Ekkel, E. D., Spoolder, H. A. M., Hulsegge, I., and Hopster, H. (2003). Lying characteristics as determinants for space requirements in pigs. *Appl. Anim. Behav. Sci.* 80, 19–30. doi: 10.1016/S0168-1591(02)00154-5

Geers, R., Goedseels, V., Parduyns, G., Nijns, P., and Wouters, P. (1990). Influence of floor type and surface temperature on the thermoregulatory behaviour of growing pigs. *J. Agric. Res.* 45, 149–156. doi: 10.1016/S0021-8634(05)80146-5

Götz, S., Raoult, C. M. C., Reiter, K., Wensch-Dorendorf, M., and von Borell, E. (2022). Lying, feeding and activity preference of weaned piglets for LED-illuminated vs. dark pen compartments. *Animals* 12, 202. doi: 10.3390/ani12020202

Hacker, R. R., Ogilvie, J. R., Morrison, W. D., and Kains, F. (1994). Factors affecting excretory behavior of pigs. *J. Anim. Sci.* 72, 1455–1460. doi: 10.2527/1994.7261455x

Hillmann, E., Mayer, C., Gygax, L., and Schrader, L. (2005). Effect of space allowance on behavioural and adrenocortical reactions to elevated temperatures in fattening pigs. *Landbauforschung. Völkenrode.* 55, 255–260.

Hillmann, E., Mayer, C., and Schrader, L. (2004). Lying behaviour and adrenocortical response as indicators of the thermal tolerance of pigs of different weights. *Anim. Welf.* 13, 329–335. doi: 10.1017/S096272860002844X

Höne, U., Krause, E. T., Bussemas, R., Traulsen, I., and Schrader, L. (2023). Usage of outdoor runs and defaecation behaviour of fattening pigs. *Appl. Anim. Behav. Sci.* 258, 105821. doi: 10.1016/j.applanim.2022.105821

Huynh, T. T. T., Aarnink, A. J. A., Gerrits, W. J. J., Heetkamp, M. J. H., Canh, T. T., Spoolder, H. A. M., et al. (2005). Thermal behaviour of growing pigs in response to high temperature and humidity. *Appl. Anim. Behav. Sci.* 91, 1–16. doi: 10.1016/j.applanim.2004.10.020

ITW Initiative Tierwohl. (2023) ITW Initiative Tierwohl - Gesellschaft zur Förderung des Tierwohls in der Nutztierhaltung mbH. Available at: https://initiative-tierwohl.de (Accessed February 13, 2023).

Jensen, T., Nielsen, C. K., Vinther, J., and D'Eath, R. B. (2012). The effect of space allowance for finishing pigs on productivity and pen hygiene. *Livest. Sci.* 149, 33–40. doi: 10.1016/j.livsci.2012.06.018

Larsen, M. L. V., Bertelsen, M., and Pedersen, L. J. (2017). How do stocking density and straw provision affect fouling in conventionally housed slaughter pigs? *Livest. Sci.* 205, 1–4. doi: 10.1016/j.livsci.2017.09.005

Larsen, M. L. V., Bertelsen, M., and Pedersen, L. J. (2018). Review: Factors affecting fouling in conventional pens for slaughter pigs. *Animal* 12, 322–328. doi: 10.1017/S1751731117001586

Larsen, M. L. V., Bertelsen, M., and Pedersen, L. J. (2019). Pen fouling in finisher pigs: Changes in the lying pattern and pen temperature prior to fouling. *Front. Vet. Sci.* 6. doi: 10.3389/fvets.2019.00118

Nannoni, E., Aarnink, A. J. A., Vermeer, H. M., Reimert, I., Fels, M., and Bracke, M. B. M. (2020). Soiling of pig pens: A review of eliminative behaviour. *Animals* 10, 2025. doi: 10.3390/ani10112025

Ocepek, M., and Andersen, I. L. (2022). The effects of pen size and design, bedding, rooting material and ambient factors on pen and pig cleanliness and air quality in fattening pig houses. *Animals* 12, 1580. doi: 10.3390/ani12121580

Olczak, K., Nowicki, J., and Klocek, C. (2015). Pig behaviour in relation to weather conditions – a review. *Ann. Anim. Sci.* 15, 601–610. doi: 10.1515/aoas-2015-0024

Opderbeck, S., Keßler, B., Gordillo, W., Schrade, H., Piepho, H.-P., and Gallmann, E. (2020). Influence of increased light intensity on the acceptance of a solid lying area and a slatted elimination area in fattening pigs. *Agriculture* 10, 56. doi: 10.3390/agriculture10030056

Philippe, F.-X., Cabaraux, J.-F., and Nicks, B. (2011). Ammonia emissions from pig houses: Influencing factors and mitigation techniques. *Agric. Ecosyst. Environ.* 141, 245–260. doi: 10.1016/j.agee.2011.03.012

Pinheiro, J., Bates, D.R Core Team (2023) nlme: Linear and Nonlinear Mixed Effects Models. R package version 3. Available at: https://CRAN.R-project.org/package=nlme.

Rantzer, D., and Svendsen, J. (2001). Slatted versus solid floors in the dung area: Comparison of pig production system (moved versus not moved) and effects on hygiene and pig performance, weaning to four weeks after weaning. *Acta Agriculturae. Scandinavica. Section. A. – Anim. Sci.* 51, 175–183. doi: 10.1080/09064700120126

RStudio Team (2022). *RStudio: Integrated Development Environment for R* (Boston, MA: RStudio, PBC). Available at: http://www.rstudio.com.

Savary, P., Gygax, L., Wechsler, B., and Hauser, R. (2009). Effect of a synthetic plate in the lying area on lying behaviour, degree of fouling and skin lesions at the leg joints of finishing pigs. *Appl. Anim. Behav. Sci.* 118, 20–27. doi: 10.1016/j.applanim.2009.02.006

Schrader, L., Czycholl, I., Krieter, J., Leeb, C., Zapf, R., and Ziron, M. (2016). *Tierschutzindikatoren: Leitfaden für die Praxis – Schwein. Vorschläge für die Produktionsrichtung Sauen, Saugferkel, Aufzuchtferkel und Mastschweine* (Darmstadt: KTBL).

Spoolder, H. A. M., Aarnink, A. A. J., Vermeer, H. V., van Riel, J., and Edwards, S. A. (2012). Effect of increasing temperature on space requirements of group housed finishing pigs. *Appl. Anim. Behav. Sci.* 138, 229–239. doi: 10.1016/j.applanim.2012.02.010

Taylor, N., Prescott, N., Perry, G., Potter, M., Le Sueur, C., and Wathes, C. (2006). Preferences of growing pigs for illuminance. *Appl. Anim. Behav. Sci.* 96, 19–31. doi: 10.1016/j.applanim.2005.04.016

TierSchNutztV. (2021). Tierschutz-Nutztierhaltungsverordnung in der Fassung der Bekanntmachung vom 22. August 2006 (BGBl. I S. 2043), die zuletzt durch Artikel 1a der Verordnung vom 29. Januar 2021 (BGBl. I S. 146) geändert worden ist. Available at: https://www.gesetze-im-internet.de/tierschnutztv (Accessed February 13, 2023).

Van Putten, G. (1978). "Schwein," in *Nutztierethologie Das Verhaltenlandwirtschaftlicher Nutztiere – Eine angewandte Verhaltenskunde für die Praxis*. Ed. H. H. Sambraus (Paul Parey, Berlin-Hamburg), 168–212.

Zerboni, N. V., and Grauvogl, A. (1984). "Schwein," in *Verhalten landwirtschaftlicher Nutztiere*. Eds. H. Bogner and A. Grauvogl (Ulmer, Stuttgart), 246–296.