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Short Communication

Effects of modulating space density via the number of pigs in a pen on feeder use and feeder access in the finishing period

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HIGHLIGHTS

- The average proportion of feeder use correlated with the number of pigs in a pen.
- The pattern of feeder use throughout the afternoon did not differ across treatments.
- High density pens showed a high prevalence of feeder obstruction in the last week.
- Obstruction mainly occurred in headspaces close to the solid floor.
- The pigs seemed to avoid feeding in the middle headspace of the feeder.

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ABSTRACT

High stocking density can affect how finishing pigs access and use feeders. This study investigated how different space allowances, achieved by varying the number of pigs per pen, influenced feeder use and obstruction during the finishing period. A total of 197 pigs were assigned to one of three treatments: CON (18 pigs/pen, 0.7 m^2/pig, $n = 6$ pens), SP9 (9 pigs/pen, 1.4 m^2/pig, $n = 6$), and SP6 (6 pigs/pen, 2.8 m^2/pig, $n = 6$). Each pen had one feeder with three headspaces. At weeks 2, 5, and 10, videos were recorded between 14:30 and 16:30 and scan-sampled every 20 seconds. Feeder use was defined as a pig with its head inside a headspace; feeder obstruction as a pig sitting or lying in front of a headspace, blocking access. Queuing was also recorded. Absolute feeder use was higher in CON than in SP9 and SP6 ($P < 0.01$), although use across the afternoon did not differ clearly between treatments. However, feeder obstruction was significantly more frequent in CON, particularly at week 10 ($P < 0.01$), with up to 75% of observations showing all headspaces blocked. Queuing was rare but mostly observed in CON. Across treatments, pigs preferred the outer headspaces ($P < 0.01$), while obstruction occurred most often near the solid floor ($P < 0.01$). In conclusion, high stocking density increases feeder obstruction, especially in later finishing stages. Reducing pig numbers per pen may improve access, but further refinement of pen and feeder design is recommended.

1. Introduction

Intensive conventional husbandry is commonly characterized by a relatively high stocking density resulting from a large number of pigs housed within one pen. As a result of this strategy, pigs often run into competition for access to pen resources, including the feeder, especially in the fattening period. Studies have for instance shown that finishing pigs housed in crowed pens eat fewer meals of greater quantity, and have a longer latency to their next meal than pigs in uncrowded pens, notably at the end of the finishing period (Street and Gonyou, 2008; Nielsen et al., 1996). Feeding is also a social behaviour, which means that many individuals may want to access the feeder simultaneously (Nielsen et al., 1996). While feed is dispensed ad libitum and is normally accessible at all times in most systems, the possibility for the majority of pigs to access the feeder at once is often limited. This mismatch between natural behaviours and rearing conditions may further encourage competition, potentially resulting in agonistic behaviours including displacement, aggression and biting (Botermans et al., 2000). In addition, social hierarchy is thought to play an important role in feeding behaviour, with high-ranking pigs having privileged access to the feeder. As a result, low ranking pigs may not be able to feed as much as their pen mates or need to change their feeding patterns, accessing the

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feeder for a shorter duration and ingesting less (Chen et al., 2021). To modulate these behavioral issues, studies previously focused on modulating feeder layouts (e.g. gap between headspaces or number of headspaces) to improve pig feed intake and welfare issues (Mayers et al., 2012; Magowan et al., 2008).

Yet, space availability often remains a limiting factor in how freely pigs access the feed, regardless of the feeder design. To improve pig welfare, pens can be built with functional areas, e.g. a solid area where pigs are expected to rest and sleep, and a slatted floor where pigs can be more active and feed (Pedersen, 2018). However, in pens with a high stocking density, some pigs may not have the choice to rest outside of the solid floor due to space constraints, especially in the late fattening period (Coutant et al., 2025a). As a result, the feeder may be obstructed by other pigs, preventing pigs from accessing the feed (Street and Gonyou, 2008).

In an effort to facilitate feeder access, a reduction in the number of pigs housed per pen may therefore be a solution. This will simultaneously increase space availability and decrease the number of pigs per feeder head. Previous studies have shown a positive effect of increased space allowance per pig on time spent eating and feed intake (Vermeer et al., 2014), while decreasing the number of pigs per feeder spaces in a pen increased growth rate and resulted in a reduction of body lesions (López-Vergé et al., 2018). Yet, the effect of reducing the number of pigs in a pen on the use of feeders, as observed directly rather than by proxy of growth, remains to be further investigated. The aim of this study was therefore to investigate how the number of pigs per pen (18, 9 or 6 pigs) modulates the use and access to the feeder. The study focused on the use of the feeder, the prevalence of feeder obstruction throughout the fattening period, as well as the posture displayed by pigs while at the feeder.

2. Materials and methods

2.1. Ethical approval

Ethical review and approval were not required for this study since the experimental procedures and care of animal under study were carried out in accordance with the Ministry of Food, Agriculture and Fisheries, The Danish Veterinary and Food Administration under act 474 of 15. May 2014 and executive order 2028 of 14. December 2020.

2.2. Animals

The study took place at the experimental facility of AU-Viborg (Aarhus University, Tjele, Denmark) between September and November 2023. A total of 197 pigs (DanBred genetics; Landrace x Yorkshire x Duroc) came from a local breeder at approx. 30 kg and remained in the study until being sent to slaughter at approx. 110 kg, corresponding to 11 experimental weeks.

2.3. Management conditions

The pens (2.48 × 5.45 m) were divided into three equal-sized areas featuring a combination of solid, drained, and slated flooring (see Fig. 1). In each pen, a feeder (1.02 × 0.38 m) containing three individual headspaces (approx. 35 cm length) with shoulder separation was placed alongside the pen wall in the drained area. Each pen also featured two drinking nipples, and two fixed wooden beams for environmental enrichment in compliance with EU legislation. Each pen was additionally enriched with a 12 L bucket of straw scattered across the solid floor every day at 11:00. An automatically controlled sprinkler system (SKOV A/S, Roslev, DK) was in place above the slated floor of each pen. The lighting was set to 182 lx and lights were on from 7:00 to 22:00. The indoor temperature followed a standard curve, beginning at 21 °C upon arrival to 17 °C in week 8 and onwards. The pigs were fed a combination of two commercial pelleted dry feed provided ad libitum.

2.4. Treatments

Upon arrival, the pigs were randomly assigned to a pen, which was then allocated to one of three treatments. Each treatment was implemented in six pens, randomly distributed across two experimental rooms to ensure a balanced representation of treatment pens in each room and its subsets.

In control pens (CON), pigs were housed at a conventional density of 0.7 m^2 per pig, corresponding to 18 pigs per pen (approx. 5.8 cm of feeder space per pig). In Space 9 pens (SP9), pigs were housed at a density of 1.4 m^2 per pig, corresponding to 9 pigs per pen (approx. 11.7

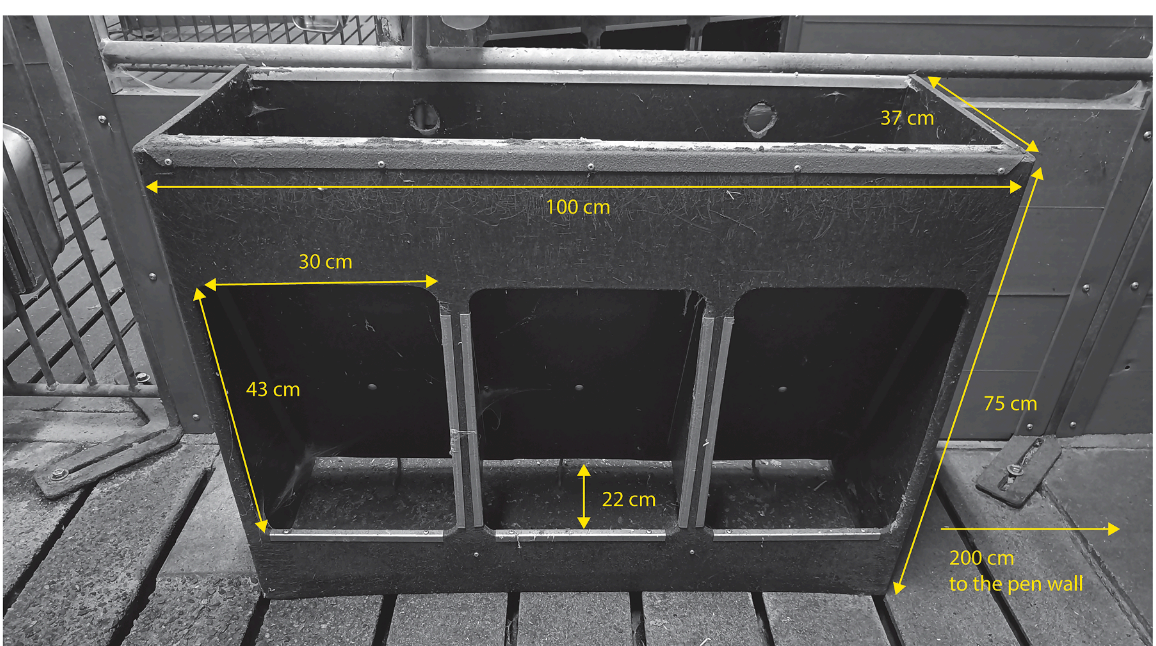

Fig. 1. Photography of the feeder containing three individual headspaces.

cm of feeder space per pig). Finally, in Space 6 pens (SP6), pigs were housed at a density of 2.1 m^2 per pig, corresponding to 6 pigs per pen (approx. 17.5 cm of feeder space per pig).

2.5. Behavioral observations

Video recordings were obtained from 2-dimensional cameras fixed above each pen (model DS-2CD2145FWD-I, Hikvision, China). The recordings were observed for 2 h during the afternoon on an undisturbed day (Saturday, 14:30 to 16:30) at experimental week 2, 5 and 10. Scan sampling was used with a 20 sec interval to determine whether any of the feeders headspace was being used by a pig or obstructed by pig, and if so what posture (laying, sitting, standing) the pig feeding/obstructed pig was displaying. The observer also recorded whether any pig was queuing to get access to a feeder space (ethogram in Table 1). Fig. 2 displays the location of each feeder space (1, 2, 3) as well as the zone of observation for the queuing behaviour. All observations were performed by a single observer using the BORIS software (Friard and Gamba, 2016).

2.6. Statistical analyses

All statistical analyses were conducted in R version 4.3.2 (R Core Team, 2023) with a 5 % significance level ($P < 0.05$).

Feeder use and feeder obstruction were aggregated to the total sum of scans with feeder headspace being used by pigs, total sum of scans with feeder headspace being obstructed by pigs, and the sum of scans times 3 to get total number of feeder headspaces per pen and week (54 observations; the latter calculated to be able to calculate the response for the beta-binomial model). Both feeder use and obstruction were analysed as a beta-binomial response using the "glmmTMB" package (Brooks et al., 2017). The models included treatment (Control, Space 9, Space 6), week (2, 5, 10) and their interaction as fixed effects, and pen as a random effect.

Feeder site preference was investigated by aggregating to the total sum of scans with feeder use and feeder obstruction for each feeder headspace, pen and week (162 observations) and analysed in relation to the total sum of scans with feeder use and feeder obstruction for each pen and week. Feeder site preference was analysed as a beta-binomial response with the model including feeder site (1, 2, 3), treatment, week and the interaction between feeder site and week as fixed effect, and pen as a random effect.

Posture of pigs while using or obstructing the feeder were also aggregated to the total sum of scans with pigs using and obstructing and the total sum of these scans with pigs lying, sitting and standing per pen (54 observations). Both use and obstruction posture were analysed as a beta binomial response with the model including treatment, posture (lying, sitting, standing) and their interaction as fixed effects, and pen as random effect.

For all models, the potential temporal correlation between the three weeks were not explicitly modelled. All model assumptions were tested using the 'DHARMa' package (Hartig, 2022), and post-hoc analysis was conducted when relevant using the 'emmeans' package (Lenth, 2024).

The prevalence of pigs queuing was low, and thus not analysed inferentially, but only descriptively.

Table 1
Ethogram used for observation of feeder use using a 20-sec scan sampling over 2 h.

Category	Description
Feeder use	The feeder space is being used by a pig (a pig has its head into the feeder space)
Feeder obstruction	The feeder space is being obstructed by a pig (a pig is not using the feeder but is blocking access to the feeder with any part of its body except the head)
Pig queuing	Number of pig queuing (being directly behind a feeding or obstructing pig, head towards the feeder within the defined zone displayed in Fig. 1)

For each category, the observer recorded which feeder was being used (Feeder 1, 2, 3) as well as the posture of the pig.

3. Results

3.1. Feeder use

Out of the 19,438 scans, the feeder was used by 0, 1, 2 and 3 pigs in 49, 24, 18 and 9 % of the scans. The feeder was not used in the Control pens in 37 % of the scans versus 64 % of the scans in the Space 6 pens. The feeder was used by 3 pigs in the Control pens in 16 % of the scans, versus only 7 and 4 % of the scans in the Space 9 and Space 6 pens, respectively.

The feeding pattern, calculated as the percentage of feeder headspaces being used on average every 2 min during the two hours observation across the three observation weeks, did not show clear differences among the treatments (see Fig. 3).

Both treatment (x_2^2=46.29, $P < 0.001$) and week (x_2^2=64.28, $P < 0.001$) showed a significant effect on feeder use (see Fig. 4). Across all weeks, feeder use was greater in the Control pens, intermediate in Space 9, and lower in Space 6 ($P < 0.001$ for all pair-wise comparisons). Across all treatments, feeder use was lower in week 10 compared to week 2 and 5 ($P < 0.001$ for both pair-wise comparisons).

3.2. Feeder obstruction and queuing

A tendency for an interaction between treatment and week was found for feeder obstruction (x_4^2=8.96, $P = 0.062$), with a higher percentage of feeder obstruction in the Control pens compared to Space 9 pens in week 10 and compared to Space 6 pens in week 5 and 10 (see Fig. 5).

Queuing was observed very rarely, with an average of less than 1 pig queuing per observation. Looking at absolute numbers, the data showed that queuing was mostly observed at week 5 (over 510 cumulated recordings of a pig queuing vs. 121 in week 2 and 51 in week 10) and was numerically more prevalent in Control pens (505 cumulated recordings) compared to Space 9 and Space 6 pens (69 and 111 cumulated recordings, respectively).

3.3. Posture during feeder use and obstruction

Posture of pigs during feeder use differed significantly (x_2^2=324.26, $P < 0.001$), with estimated probabilities of 1.0, 7.5, and 92.3 % for lying, sitting and standing, respectively. Posture of pigs during feeder obstruction also differed significantly (x_2^2=155.05, $P < 0.001$) with estimated probabilities of 70.4, 8.1, and 24.2 % for lying, sitting and standing, respectively. Fig. 6 shows how the posture of pigs during feeder use and feeder obstruction depended numerically on treatment. Descriptive analysis (not reported) additionally showed no effect of the week on the posture of pigs.

3.4. Feeder site preference

Feeder site preference during feeding showed a significant interaction between feeder site and week (x_4^2=39.88, $P < 0.001$) with higher use of feeder 3 than feeder 1 and 2 in week 2, a lower use of feeder 2 than feeder 1 and 3 in week 10, and a numerical lower use of feeder 2 in all weeks (see Fig. 7). There was a significant lower obstruction of feeder 3 than feeder 1 and 2, independent of the week (x_2^2=31.53, $P < 0.001$), with (see Fig. 7).

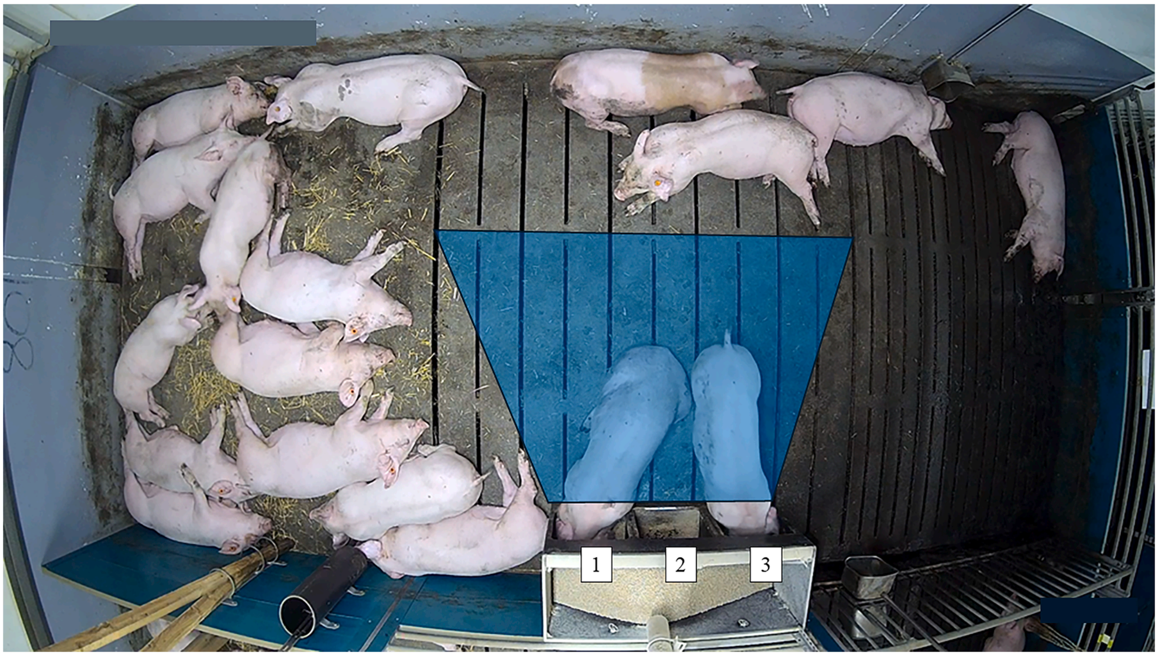

Fig. 2. Snapshot of a recording from a pen showing how the feeder headspaces were labelled (Feeder site 1, 2, 3) as well as the zone of observation for the queuing behaviour (represented in blue).

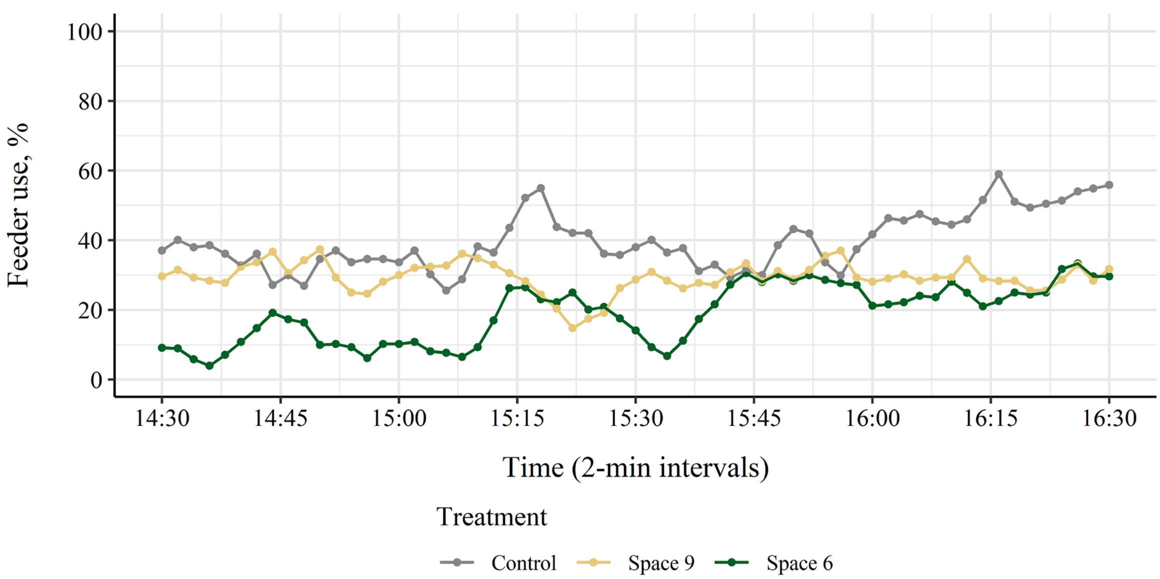

Fig. 3. Average percentage of feeder use across the two hours observation for each space treatment. Control: 18 pigs per pen (0.7 m^2 per pig), Space 9: 9 pigs per pen, Space 6: 6 pigs per pen (2.1 m^2 per pig).

4. Discussion

The study aimed to investigate how a reduction of the number of finisher pigs housed in a pen, and resulting reduction in stocking density, impacts how pigs use and access the feeder. In this design, the pigs were fed pelleted feed ad libitum, dispensed in a feeder with three headspaces. The amount of data collected was limited (6 pens per treatment, one afternoon per finisher period), but the results still showed clear patterns.

In terms of proportion of feeder use, the results showed a linear relationship between the number of animals per pen and the proportion of feeder used across the finishing period. This outcome was to be expected, as with more pigs in a pen comes a higher likelihood of a pig using the feeder. However, this change in feeder use did not seem to lead to a change in feeding pattern over two hours observed. Feeding being a social behaviour in pigs (Clayton, 1978), we hypothesized that pigs would show signs of social facilitation, with peaks of full feeder use (i.e., all 3 feeder spaces used simultaneously) alternating with periods of no feeder use, especially in the pens with a reduced number of pigs. In contrast, the results showed a consistent use of the feeder by one or two pigs at the time throughout the afternoon, regardless of the treatment. This apparent lack of sociality in the use of the feeder may be the result of different factors, including an insufficient feeder headspace (both in terms of number and dimensions) or a high level of competition at the feeder (Boumans et al., 2018). It is also possible that conventionally kept pigs adapt their feeding pattern on a more general level in response to the competition to access the feeder or because of a lack of stimuli as compared to more extensive systems, leading to increased visits to the

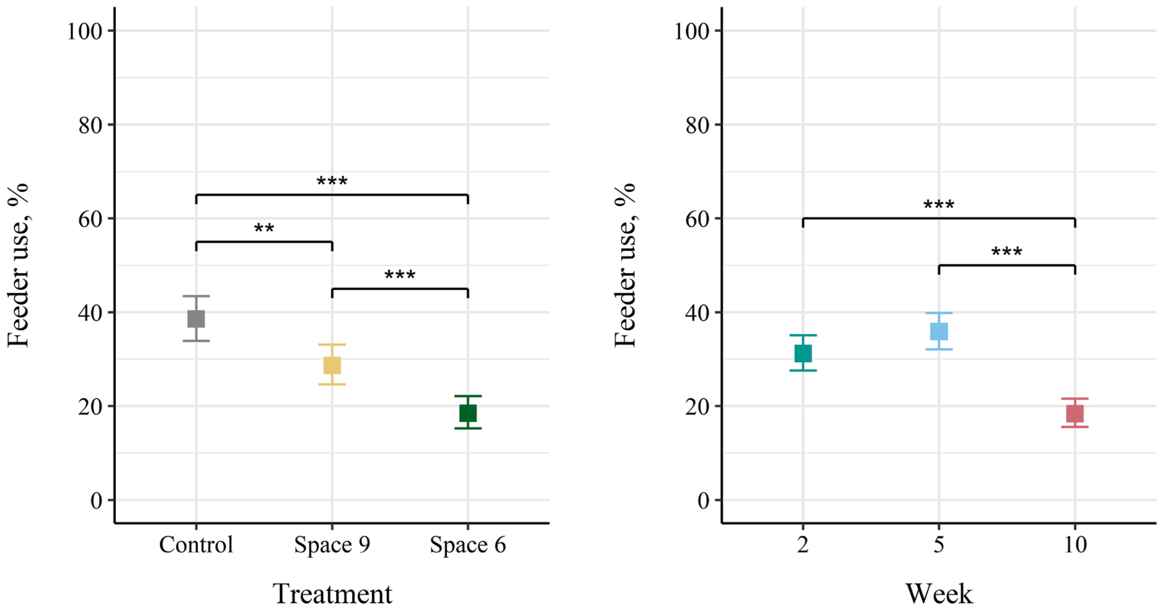

Fig. 4. Percentage of feeder use per treatment (left) and per week (right). Model estimates ± 95 % confidence intervals. Control: 18 pigs per pen (0.7 m^2 per pig), Space 9: 9 pigs per pen, Space 6: 6 pigs per pen (2.1 m^2 per pig). Post-hoc analysis was conducted to compare all space levels and all weeks to each other, while only the significant pair-wise comparisons are shown. $^{**}P < 0.01$, $^{***}P < 0.001$.

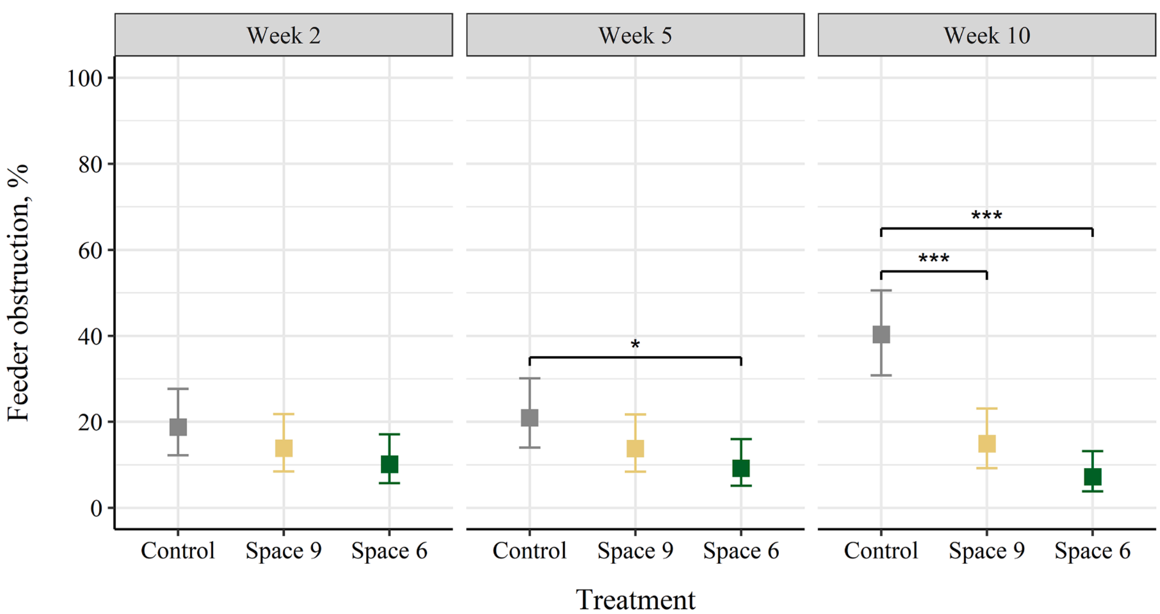

Fig. 5. Percentage of feeder obstruction per treatment and week. Model estimates ± 95 % confidence intervals. Control: 18 pigs per pen (0.7 m^2 per pig), Space 9: 9 pigs per pen, Space 6: 6 pigs per pen (2.1 m^2 per pig). Post-hoc analysis was conducted to compare all space levels to each other within each week, while only the significant pair-wise comparisons are shown. $^{*}P < 0.05$, $^{***}P < 0.001$.

feeder regardless of hunger (Bus, 2021). Regardless of the underlying mechanisms, these patterns were observed across all space treatments. It cannot be inferred from this study, though, whether the intake of feed differed between the treatments. Previous studies have shown that increasing the number of pigs per feeder in a pen negatively impacts the pigs' body weight and average daily gain (Wastell et al., 2018; Coutant et al., 2025b), potentially because pigs' shorter meals (Bus, 2021). It can also be noted that the posture of the pigs while using the feeder tended to change with the treatment. In pens with only six pigs, pigs displayed numerically more sitting than in the other treatments, which may indicate the possibility to extend feeding duration, though previous studies have shown otherwise (Bus, 2021). Still, sitting remained. a relatively rare behaviour (< 15 % of the observations).

The most striking difference between space treatments was observed in terms of feeder access. Obstruction, i.e. the event of a pig being in the way of the feeder and preventing others from accessing it, was observed in all treatments. However, the highest proportion of obstruction was observed in the conventional density pens with 18 pigs, and especially in the last week of the finishing period. That week, some control pens showed obstruction of all three feeder heads for more than 20 min at a time, with the 'worst' pen showing obstruction of almost all feeder heads for more than 1h30 out of the 2 h observation. This result shows that some pigs were likely completely prevented from accessing the feeder for relatively long periods. Already showed by Street & Gonyou (2008),

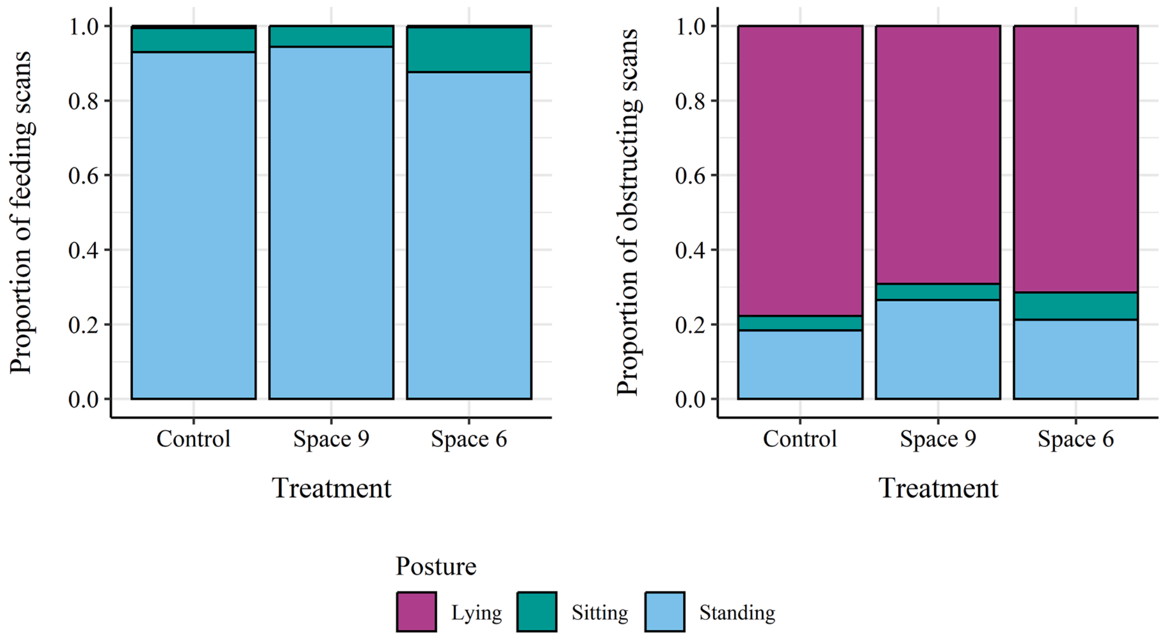

Fig. 6. Proportion of feeding scans (left, $n = 17{,}065$) and obstructing scans (right, $n = 9380$) with the pig in either lying, sitting or standing posture for each treatment across all weeks. Calculations from raw data. Control: 18 pigs per pen (0.7 m^2 per pig), Space 9: 9 pigs per pen, Space 6: 6 pigs per pen (2.1 m^2 per pig).

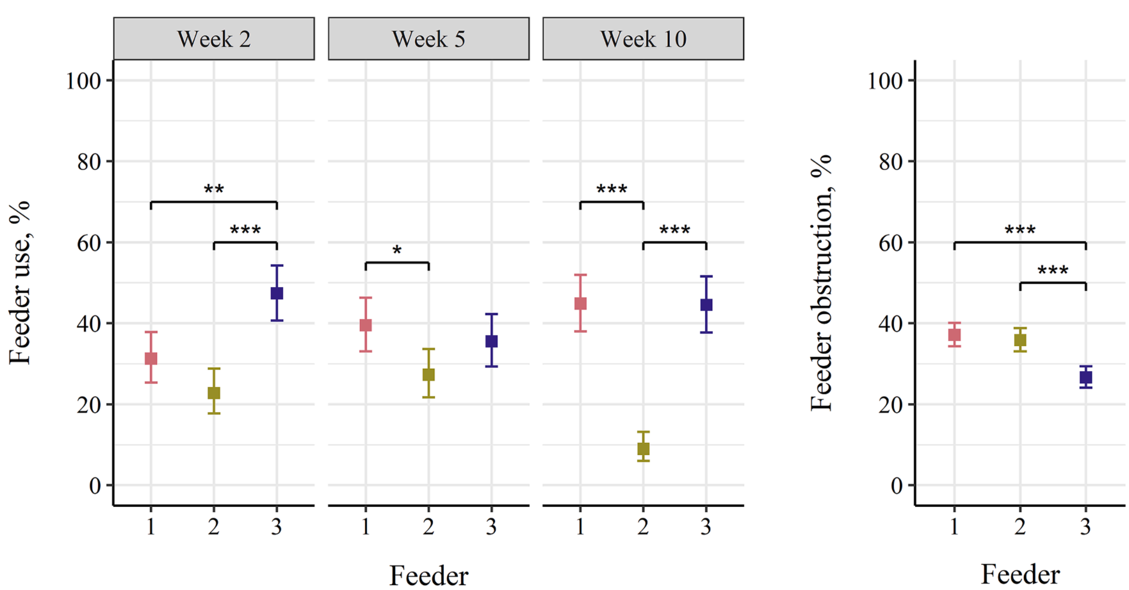

Fig. 7. Percentage of feeder use per feeder site and week (right) and feeder obstruction per feeder site (left). Model estimates ± 95 % confidence intervals; out of scans with feeder use ($n = 17{,}065$) and obstruction ($n = 9380$). Feeder 1: closest to resting area (solid floor), Feeder 2: in the middle, Feeder 3: closest to the drinking cup, slatted floor and hallway). Post-hoc analysis was conducted to compare all feeders to each other within each week (for feeder use only), while only the significant pair-wise comparisons are shown. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

this issue likely resulted in reduced feed intake and may partly explain why feeder use was the lowest in week 10 (although pigs may have also reached their finishing weight by then). Besides feed intake, the hampering of feeder access may have also created frustration leading to displacement and/or aggression and may even be a risk factor for tail biting (Kobek-Kjeldager et al., 2022). Overall, the high prevalence of feeder obstruction in high density pens in the last weeks of the finisher period is a considerable issue for both pig welfare and performance. Proportion of queuing was also numerically four times higher in control pens than in the pens with a lower number of pigs. Nevertheless, queuing behaviour remained overall rare, showing that pigs probably changed their motivation if the feeder was occupied, rather than waiting.

Besides looking at treatment effect, observing the characteristics of the feeder usage also provides cues as to limitations in the feeder design. The results showed that pigs seemed to favor feeding from the feeder sites 1 and 3, i.e. the feeder heads on the outside, which is probably explained by a lower level of comfort and/or higher risk of agonistic behaviour in the middle space. This result is consistent with the hypothesis that the feeder space provided was not satisfactory, neither in number of spaces nor in dimensions. It is also notable that most obstruction happened on the feeder sites 1 and 2, as a likely consequence of their proximity to the solid floor, which is a preferred resting place for pigs (Larsen et al., 2017). This hypothesis is supported by the fact that the majority of pigs obstructing the feeder were observed to be lying. This phenomenon is an issue for both pigs wanting to access the feeder and pigs trying to rest on the solid floor, being potentially disturbed (Coutant et al., 2025a). These outcomes of the study therefore suggest that the design, dimension and location of the feeder heads remain limiting factors in the use and access of the feeder, especially in systems with a high space density.

5. Conclusion

Reducing the number of pigs per pen and subsequently space density did not seem to affect how pigs use the feeder throughout the afternoon. However, it increased the accessibility of the feeder, notably by reducing the prevalence of feeder spaces being obstructed, especially in the last weeks of the finishing period. Further studies are needed to elucidate how pen and feeder designs can optimize feeding behaviour in fattening pigs.

CRediT authorship contribution statement

Mathilde Coutant: Writing – original draft, Supervision, Methodology, Data curation. **Noémie Menard:** Writing – review & editing, Methodology, Investigation. **Lene J. Pedersen:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Mona L.V. Larsen:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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