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Welfare of Finishing Pigs – Effect of Decreased Stocking Density on Animal Welfare and Production Variables

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Preface

First, I would like to thank my supervisor Inger Lise Andersen for your patience and good help throughout the writing process. And to my supervisor Marko Ocepek for feedback and good and informative courses at NMBU. Also, a big thanks to Anne Stine Ekker in Felleskjøpet for good feedback and for quick replies to my e-mails whenever I was stuck. And to the farmer, Halvor Moshus, for hospitality, cups of coffee, and for answering all my questions about pigs.

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Lastly, I would like to thank my dog Vega for forcing me to go outside – at least a few times a day.

Abstract

Modern pig farms are developed to be as economical and as efficient as possible, which has led to intensive livestock production systems. In recent years, both consumers and politicians have shown an increased interest in animal welfare. Policy makers are wondering how they can improve animal welfare, while keeping livestock production economically sustainable for farmers.

This thesis is a part of a project that aims to investigate the consequences of reducing animal stocking density to improve welfare in pig production, which has been suggested by several non-governmental organizations (NGO's) as a possible measure. It is crucial to evaluate the consequences of such implementations, before making changes to existing regulations. To the best of our knowledge, such experiments with focus on animal welfare and carcass traits has never been done before in Norway. The aim of this master's thesis is to investigate how stocking density, as well as two different feed types, affect welfare, production, and carcass traits in finishing pigs.

A decrease in fear responses and an increase in contact seeking behavior was observed for pigs in both density groups. Pigs housed in lower-density pens (1.5 m^2/pig) had a higher prevalence of tail wagging, a lower prevalence of negative welfare indicators such as tail down. Pigs housed in higher-density pens (1.0 m^2/pig), had a higher prevalence of ear, body and tail lesions compared to pigs in lower-density pens (1.5 m^2/pig). In the start of the finishing period, there was little difference in body, ear and tail lesions when comparing the two density groups. There was a decrease in lesions over time, except for an increase in tail lesions in pigs housed in the higher-density pens (1.0 m^2/pig).

The pigs were weighed three times during the experiment, and data concerning slaughter weight and meat percentage was collected from the slaughterhouse. The data concerning growth rate showed no significant difference when comparing pigs from the two density groups. There was observed an effect of sex on production variables, as the female pigs had a higher slaughter weight and meat percentage than the male pigs. Pen and pig cleanliness was also registered, as well as lameness and hernias. Stocking density had no impact on these parameters.

Sammendrag

Moderne svineproduksjon er utviklet for å være så økonomisk og effektiv som mulig, noe som har medført intensive produksjonssystemer. I senere år har både forbrukere og politikere vist en økt interesse for dyrevelferd. De som utformer retningslinjer, lurer på hvordan de kan forbedre dyrevelferden på en slik måte at det ikke går på bekostning av at matproduksjon er økonomisk bærekraftig.

Denne oppgaven er en del av et prosjekt som har som formål å undersøke konsekvensene av redusert dyretetthet for å forbedre velferd i svineproduksjon, noe som er foreslått av dyrevernorganisasjoner som et mulig tiltak. Det er viktig å utrede konsekvensene av slike tiltak før man gjør endringer i eksisterende forskrifter. Så vidt vi kjenner til, er ikke slike eksperimenter med søkelys på dyrevelferd og slakteegenskaper gjennomført i Norge tidligere. Formålet med denne masteroppgaven er å undersøke hvordan dyretetthet, i tillegg til to ulike typer fôr, påvirker velferd, produksjon og slakteegenskaper hos slaktegris.

En nedgang i fryktresponser og en økning i kontaktsøkende atferd ble observert for griser i begge tetthetsgrupper. Griser i binger med lavere dyretetthet (1.5 m^2/gris) hadde høyere forekomst av logring, og lavere forekomst av negative velferdsindikatorer, som rett hale. Griser i binger med høyere dyretetthet (1.0 m^2/gris) hadde høyere forekomst av øre-, kropp- og halesår, sammenliknet med griser i binger med lavere dyretetthet (1.5 m^2/gris). I starten av forsøksperioden var det liten forskjell mellom gruppene i forekomst av sår. Det var en nedgang i forekomst av sår over tid i begge gruppene, med unntak av en økning i halesår hos griser i binger med høyere dyretetthet (1.0 m^2/gris).

Grisene ble veid tre ganger i løpet av slaktegrisperioden, og data for slaktevekt og kjøttprosent ble innhentet fra slakteriet. Dataene for tilvekst viste ingen signifikant forskjell når man sammenliknet de to tetthetsgruppene. Det ble observert en effekt av kjønn med tanke på produksjonsvariabler, purkene hadde en høyere slaktevekt og kjøttprosent enn galtene. Renhet for griser og binger ble også registrert, i tillegg til halthet og brokk. Dyretetthet hadde ingen påvirkning på disse parameterne.

Table of content

1.0 Introduction

1.1 The background of the study

In recent years, both consumers and politicians have shown an increased interest in animal welfare. Policy makers are wondering how they can improve animal welfare, while keeping livestock production economically sustainable for farmers. Balancing animal welfare and economic sustainability is one of the major challenges in modern livestock farming.

In 2021, the Minister of Agriculture and Food stated that there will be a new "stortingsmelding" about animal welfare. It is necessary to investigate the consequences of potential new measures that can be relevant to increase the animal welfare in Norwegian pig production. One practical measure that can be implemented is to decrease the animal stocking density by reducing the number of individuals in each pen. This might be a solution for farmers who have built housing facilities to meet current animal welfare regulations regarding stocking density, without demanding them to invest in new housing facilities. It is vital to thoroughly examine the consequences of prospective changes in the Animal Welfare Act before these are determined. The aim of this master's thesis is to evaluate the effect of decreasing stocking density by increasing the floor space available from 1.0 m^2 to 1.5 m^2 per pig.

1.2 Legislations regarding stocking density

The European directive on the protection of pigs has minimum standards for the keeping of pigs in the EU. It sets a minimum space allowance for pigs, which is dependent on the size of the animals. For finishing pigs up to 110 kg, the minimum floor space allowance is 0.65 m^2 (EU-Welfare legislation on pigs, 2010). The Finnish legislation goes beyond the European standards, with a minimum of 0.9 m^2 for finishing pigs up to 107 kg. Norwegian regulations fall in between the European and the Finnish regulations. According to the current Norwegian Animal Welfare Act, § 26 (Feb 22) the minimum space allowance for finishing pigs that weigh between 85 - 110 kg is 0.8 m^2 per pig. For pigs heavier than 110 kg, the area should be at least 1.0 m^2 per pig (Norwegian Ministry of Agriculture and Food, 2003). In a study by

Valros et al. (2021) it was reported that the relatively generous space allowance required in Finland has a positive effect on welfare status of the pigs, as it has lowered the prevalence of tail biting. The effect of stocking density in pigs has been broadly studied over the years, with a definite negative effect of high stocking density on animal welfare, based on a variety of behavioral and physiological indicators (Averós et al., 2009). In a study by Estevez et al. (2006), high animal stocking density increased the frequency of aggression and behavioral problems in finishing pigs. Living in a group means having to compete for resources, such as floor space. The more limited those resources are, the higher the risk of aggressive behavior (Estevez et al., 2006). Albernaz-Gonçalves et al. (2021) also found that higher stocking density represents a common stressor of intensive farming, which increases the risk of developing abnormal and stereotypic behaviors, such as tail biting. A correlation has also been found between stocking density and the levels of stress hormones (corticosteroids) in pigs, suggesting that decreasing stocking density can be an effective measure to increase animal welfare (Cornale et al., 2015).

1.3 Griseløftet

The project "Griseløftet" is owned by Nortura, and created in a collaboration with NMBU, Norsvin, Felleskjøpet, and Fjøssystemer. The aim of the project is to improve the welfare of finishing pigs by investigating how different parameters affect animal welfare, production, and carcass traits on an individual level, with special focus on the animals' physical and social environment. The purpose is to expand and document several potential measures to improve animal welfare in the pig industry, as a response to the consumers increasing expectations and demands.

"Griseløftet" focuses on the physical and social environment of finishing pigs, in the form of animal density, group size, human-animal interactions, handling and management and air quality. The project contains field experiments at 87 chosen Norwegian pig farms, with both longitudinal studies and experimental trials (Etologi Norge, 2022). The aim of the project is to develop solutions and tools to improve the animal welfare in finishing pig production. The project also seeks to find connections between welfare improving solutions and carcass quality in finishing pigs (Nortura, 2019).

1.4 Animal welfare and density

Animal welfare is defined and measured in a variety of ways, where some emphasize biological function, whereas others focus on mental state and emotional well-being. The most well-known definition of animal welfare is by Donald M. Broom, an English biologist and professor of animal welfare at Cambridge University. His definition is that *"the welfare of an individual is its state as regards its attempts to cope with its environment"* (Broom, 1986). The ethology department at NMBU has developed a modified variation of his definition, which is that *"the welfare of an individual is its subjective experience of its mental and physical state as regards its attempts to cope with its environment"* (Etologi Norge, 2022). This definition emphasizes how the individual perceives their situation, both mentally and physically. This definition is used as the basis for the Norwegian Animal Welfare Act, and is the basis for welfare evaluations throughout this thesis.

Farm animals living in groups are competing for limited resources, such as space for feeding or drinking, access to rooting material, and floor space to rest and move around freely. Higher stocking density, meaning more limited floor space, has been related to severe environmental, social, and psychological stress (Li et al., 2020). The difference between high- and low-ranked individuals increases in more competitive and challenging environments, as the low-status animals tend to suffer in competitive conditions (Andersen & Bøe, 2007).

The extent of poor welfare in pigs reared for meat production is great in most parts of the world because the space and resources provided are insufficient and the needs of the animals are not met (Broom, 2017). Housing with an increased space allowance has advantages considering animal welfare in the long term, because of reduced cortisol levels and increased immunological responsiveness due to more animal-friendly conditions (Barnett et al, 1992).

1.5 Purpose and hypotheses

The purpose of this study was to investigate the effect of two different stocking densities (1.5 m^2/pig vs. 1.0 m^2/pig) in the form of increased available floor space, using tail indicators, lameness, hernia, and the prevalence of ear, body, and tail lesions as selected indicators of welfare to measure their mental and physical state. We also want to investigate the effect of stocking density (1.5 m^2/pig vs. 1.0 m^2/pig), and two different feed types on growth performance and carcass traits in finishing pigs.

Hypotheses:

Decreased stocking density in the form of increased floor space available (1.5 m^2/pig vs. 1.0 m^2/pig) will result in better animal welfare, indicated by lower prevalence of fear responses and higher prevalence of contact seeking behavior towards humans, more positive tail indicators such as curled and wagging tails, lower prevalence of tail down, and fewer ear, body, and tail lesions.

Decreased stocking density in the form of increased floor space available (1.5 m^2/pig vs. 1.0 m^2/pig) will result in an increased daily and total growth performance.

2.0 Material and methods

2.1 Experimental design and treatment

The experiment was conducted as a part of project 3703 “Griseløftet”, owned by Nortura SA, completed at Felleskjøpets producer of finishing pigs in Øyer, Gudbrandsdalen. Because no potentially harmful research was performed, no permission for research involving animals was required (Norwegian Ministry of Agriculture and Food, 2015).

The unit consisted of 32 pens. Pigs were randomly allocated to one of the experimental groups, 112 pigs were placed in 16 pens with 7 pigs each and thereby 1.5 m^2 available floor space per pig (Figure 1), and 160 pigs were placed in 16 pens with 10 pigs each and thereby 1.0 m^2 available floor space per pig (Figure 2).

Figure 1. Lower-density pens (1.5 m^2/pig) in the middle of the finishing period.

Figure 2. Higher-density pens (1.0 m^2/pig) in the middle of the finishing period.

The pens had a floor space of 10.37 m^2, including the area with slatted floor and 7.32 m^2 excluding the slatted floor area (Figure 1). This means that the pigs had 1.5 m^2 available floor space in the lower-density pens (1.1 m^2 being solid floor). In the higher-density pens the pigs had 1.0 m^2 available floor space (0.73 m^2 being solid floor). All area measurements are including the feed troughs in each pen.

Table 1. Division of the floor space available for each pig

	Lower-density pens	**Higher-density pens**
Total floor area per pig including feeding trough	$\frac{3.40\ \text{m}\ x\ 3.05\ \text{m}}{7\ \text{pigs}} \approx \mathbf{1.5\ m^2}$	$\frac{3.40\ \text{m}\ x\ 3.05\ \text{m}}{10\ \text{pigs}} \approx \mathbf{1.0\ m^2}$
Solid floor space per pig including feeding trough	$\frac{2.40\ \text{m}\ x\ 3.05\ \text{m}}{7\ \text{pigs}} \approx \mathbf{1.1\ m^2}$	$\frac{2.40\ \text{m}\ x\ 3.05\ \text{m}}{10\ \text{pigs}} \approx \mathbf{0.7\ m^2}$
Feed trough space per pig	$\frac{3.05\ \text{m}}{7\ \text{pigs}} \approx \mathbf{0.4\ m}$	$\frac{3.05\ \text{m}}{10\ \text{pigs}} \approx \mathbf{0.3\ m}$

The pens were double, measuring 3.05 m x 6.80 m, including a 2.00 m x 3.05 m area with slatted floors and a tilted wall separating each pen from the next (Figure 3). The distance from the end to the tilted wall was two meters, including the feeding trough. Each pen had one drinking bowl. The floor was covered in epoxy-treated concrete, with a daily given amount of sawdust as bedding. In the corridor between the pens, there were rubber mats with built-in weights underneath.

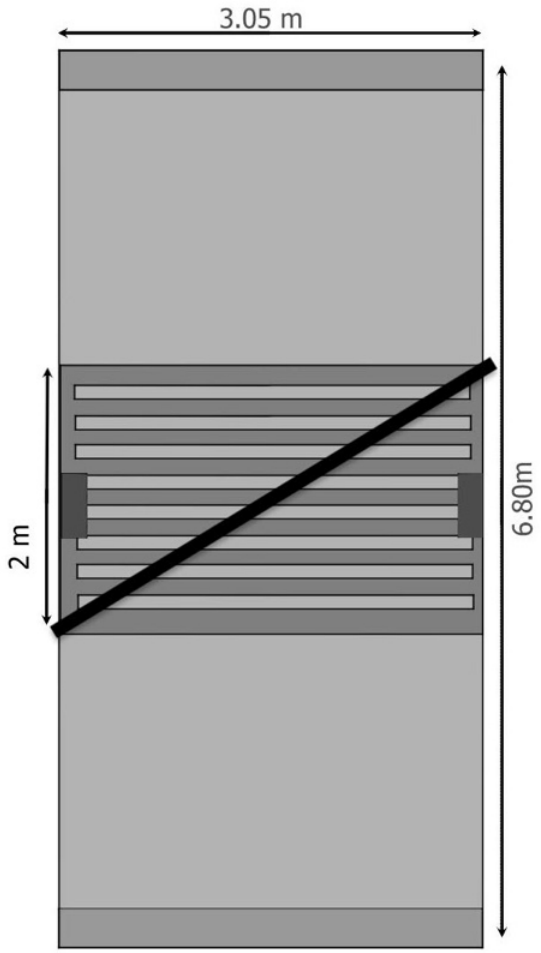

Figure 3. Pen design, with a slatted floor area in the middle and feed troughs on the short sides.

2.2 Subjects

The subjects were 272 growing pigs. The pigs were of the breed DDZL (TN70 mother and Duroc father), with a presumed 50/50 sex ratio. The pigs were approximately ten weeks old at arrival, and they all came from the same piglet producer, meaning they had all experienced similar handling and social environment before the experimental period started.

2.3 Management

Pens were cleaned daily, and rooting material was given twice a day (around 07.00 in the morning and 17.00 in the afternoon). While straw was given every morning, a different rooting material was provided in the afternoon (straw, bark, newspaper, or large high fiber pellets with 80 % beet pulp (Format Trivsel)). In addition, the pigs were given environmental enrichment such as tires hanging on a chain from the ceiling. For the pigs to be more active, and to make handling easier, they were usually let out of their pens, being able to move freely in the area between the pens during the time of the farmer care routines. Ambient temperature was approximately 20-22°C and decreased gradually down to 16-17°C towards the end of the experimental period, regulated by a ventilation system. In addition to natural light from the windows, artificial light was provided during feeding times and routine care. In the beginning of the experiment, night lights were provided as well.

No mortality occurred during the experimental period, but two pigs were taken out of the experiment. One due to back problems and the other due to lameness. Seven pigs were missing complete data from the slaughterhouse and are therefore removed from the data set and data analysis.

2.3.1 Feeding

All the pigs were fed liquid feed, consisting of concentrate and water, three times a day. The amount of feed was approximately 3 kg of feed per pig per day in average. The pigs were fed two different kinds of concentrate, a standard “Vekst 120 Control” and “Vekst 120 Solsikke”, a feed with added sunflower meal as a substitute for most of the soy. Both feeds were formulated to contain 9.68 NE/kg and 0.87 g SID lysine/kg. Half of the pigs were fed each feed type, and the feed types were randomly divided between the two density groups (1.5 m^2 vs. 1.0 m^2/pig).

2.4 Data registrations

The data was collected throughout a 10-week period during the fall of 2021. The registrations were done by 8 people consisting of master students and supervisors, according to the contrived welfare protocol (Table 2). The registrations were conducted the day after arrival (week 1 – "start of the finishing period"), in the middle of the finishing period (week 6 – "the middle of the finishing period") and before first slaughter (week 10 – "the end of the finishing period"). Body weight of each individual pig was recorded at arrival, in the middle of the finishing period, and at the time of slaughter. The pigs were sent to slaughter in week 12. The experiment consisted of a total of 65 days, from October 5th to December 9th.

2.4.1 Welfare protocol

A welfare protocol was made for this project, with descriptions for recording several variables to document the welfare and environment of finishing pigs (Table 2).

Table 2: Welfare protocol

Welfare criteria	Description
Fear-test	1. Flees immediately away with its whole body, and wants a large distance to the observer 2. Moves head / front half and/or takes a few steps away from the observer 3. Shows no visible response / remains standing or continues their behavior 4. Shows no visible response / remains standing but tries interacts with observer after some hesitation 5. Tries to interact with observer immediately
Tail position	1. Straight tail 2. Curly tail 3. Wagging
Cleanliness pigs	1. ≥ 10 % of the body is covered with manure 2. > 10 ≤ 40% of the body is covered with manure 3. > 40 % of the body is covered with manure
Cleanliness pen	1. 0 ≥ 10 % of the solid floor area is wet and/or covered with manure 2. 10 ≤ 40% of the solid floor area is wet and/or covered with manure 3. > 40 % of the solid floor area is wet and/or covered with manure
Amount of bedding	1. Nothing 2. Small amounts 3. Moderate amounts 4. Covers the solid floor completely
Mobility/lameness	0. No loss of mobility 1. Some loss of mobility, slight stiffness 2. Severe loss of mobility, severe lameness, or problems with walking
Hernia	0. The pig does not have a hernia 1. The pig has a hernia
Ear lesions	0. No ear lesions 1. Minor ear lesions (some red lesions) 2. Severe ear lesions (ears covered in red lesions or scars)
Body lesions	0. No body lesions 1. Minor body lesions (a few body lesions) 2. Severe body lesions (multiple body lesions)
Tail lesions	0. No tail lesions 1. Minor tail lesions (some tail lesions, but no damage) 2. Severe tail lesions (bleeding wounds, tail is damaged or short)

2.4.2 Fear-test

Fear-tests were done in every single pen at all three data registration time points. One person brought a handful of straw, and moved carefully into the pen, opened the door inwards, and remained standing on the inside of the pen, next to the door, in an upright position and facing the pigs. The person waited five seconds before registering the different levels of fear reactions. The hands were held low enough that the pigs could reach the straw if they wanted to. After five seconds had passed, the straw was dropped on the floor. Within one minute, the number of pigs in each category was counted, and their tail positioning was considered and registered. A second person was standing on the outside of the pen and registering the reactions directly in a work sheet in Microsoft Excel using the welfare protocol (Table 2). The pigs scoring 1 or 2 in the Fear-test were considered "fearful". The pigs scoring 5 were considered "contact seeking" (Table 2).

2.5 Statistical analysis

Microsoft Excel

Welfare scoring was noted directly in Microsoft Excel spreadsheets, for all three time points of registrations. Weight and growth data was registered in another spreadsheet after times of weighing and slaughter. After the experimental period, we added carcass data collected from the slaughterhouse.

Statistics

A mixed model (proc mixed in SAS 9.4) was used to analyze the effect of floor space per pig (m^2) and time (week 1, week 6, week 10) as fixed effects, on pig welfare traits. Pen was included as a random effect in the model. In addition to the main effects, we also tested the interaction between floor space and time. Regarding production and carcass data, a similar model was used, the only difference being that sex and feed type was included as a fixed effect in the model. All figures and tables were made using Microsoft Excel version 16.57.

The data is presented as mean with standard error, significance level was 0.05.

3.0 Results

3.1 The effect of density on behavior and welfare

Stocking density had a significant effect on the prevalence of tail down and tail wagging, minor and total ear lesions, total body lesions, and minor and total tail lesions (Table 3). There was no significant effect of density on fearful behavior, contact seeking behavior, the prevalence of curled tail, lameness, hernia or severe ear lesions, minor body lesions or severe body lesions. The prevalence is given as a percentage of the total number of pigs in each density condition, ± standard error.

3.1.1 Tail down

A significantly higher amount of the pigs had their tail down in the higher-density pens (1.0 m^2/pig) (11.3 ± 3.4) compared to the lower-density pens (1.5 m^2/pig) (4.8 ± 1.9) (Table 3; Table 4).

3.1.2 Tail wagging

Tail wagging had a significantly higher prevalence in lower-density pens (1.5 m^2/pig) (7.7 ± 2.5) compared to higher-density pens (1.0 m^2/pig) (1.9 ± 1.1) (Table 3; Table 4).

3.1.3 Ear lesions

There was a significantly higher prevalence of minor ear lesions in the higher-density pens (1.0 m^2/pig) (49.6 ± 3.6) compared to the lower-density pens (1.5 m^2/pig) (33.6 ± 3.8). In the higher-density pens (1.0 m^2/pig), there was also a significantly higher prevalence of total ear lesions (68.1 ± 3.7), compared to the lower-density pens (49.7 ± 2.4) (Table 3; Table 4).

3.1.4 Body lesions

There was a significantly higher prevalence of total body lesions in the higher-density pens (1.0 m^2/pig) (56.7 ± 5.2) compared to the lower-density pens (1.5 m^2/pig) (47.3 ± 2.2) (Table 3; Table 4).

3.1.5 Tail lesions

Minor tail lesions had a significantly higher prevalence in the higher-density pens (1.0 m^2/pig) (22.8 ± 2.7) compared to the lower-density pens (1.5 m^2/pig) (11.9 ± 2.7). There was a higher prevalence of severe tail lesions in the higher-density pens (1.0 m^2/pig) (2.9 ± 1.2), compared to the lower-density pens (1.5 m^2/pig) (0.9 ± 0.5).
There was a higher prevalence of total tail lesions in the higher-density pens (1.0 m^2/pig) (25.7 ± 2.6) compared to the lower-density pens (1.5 m^2/pig) (12.8 ± 2.8) (Table 3; Table 4).

3.2 The effect of time on behavior and welfare

Time had a significant effect on fearful and contact seeking behavior, curled tail, tail wagging, lameness, minor, severe, and total ear lesions, minor, severe, and total body lesions, as well as minor tail lesions (Table 3). Time did not have a significant effect on the prevalence of tail down, hernia or total tail lesions. In Table 4, the prevalence is given as a percentage of the total number of pigs at each time, ± standard error.

3.2.1 Fearful behavior

Fearful behavior occurred significantly more often in the start of the finishing period (17.3 ± 5.9) compared to the middle of the finishing period (0.8 ± 0.8). In the end of the finishing period, there was no fearful responses among the pigs at all (Table 3; Table 4).

3.2.2 Contact seeking behavior

Contact seeking behavior was significantly increasing throughout the experiment from the start of the finishing period (26.2 ± 6.5) to the end of the finishing period (71.4 ± 3.4) (Table 3; Table 4).

3.2.3 Curled tail and tail wagging

Time had a significant effect on curled tail and tail wagging (Table 3). Curled tail occurred significantly more often in the start (89.1 ± 3.3) and the end (90.0 ± 2.4) of the finishing period, compared to the middle of the period (82.5 ± 2.8). Tail wagging was significantly higher in the middle of the finishing period (8.4 ± 2.8) followed by the end of the finishing period (4.2 ± 1.6) and was lowest in the start of the finishing period (1.9 ± 1.1) (Table 4).

3.2.4 Lameness

Lameness was significantly increasing over time, from the start of the finishing period (2.6 ± 1.4), to the end of the finishing period (6.2 ± 1.9) (Table 3; Table 4).

3.2.5 Ear lesions

The amount of minor ear lesions was significantly higher in the start of the finishing period (55.4 ± 4.1) than in the end of the finishing period (21.3 ± 2.7). The prevalence of severe ear lesions was significantly higher in the start of the finishing period (42.0 ± 4.5) than in the end of the finishing period (1.1 ± 1.1). The total prevalence of total ear lesions was significantly higher in the start of the finishing period (97.4 ± 1.7) than in the middle (57.0 ± 4.1) and the end of the finishing period (22.4 ± 3.4) (Table 3; Table 4).

3.2.6 Body lesions

The prevalence of minor body lesions was significantly higher in the start of the finishing period (59.7 ± 7.8) than in the end of the finishing period (6.8 ± 2.6). The prevalence of severe body lesions decreased from the start of the finishing period (33.7 ± 7.3) to end of the finishing period (0.0 ± 0.0). The prevalence of total lesions on the body was high at the first registration (34.4 ± 3.6), decreased significantly to the middle (55.8 ± 5.0) and the end of the finishing period (6.8 ± 2.6) (Table 3; Table 4).

3.2.7 Tail lesions

The prevalence of minor tail lesions significantly decreased from the start of the finishing period (20.8 ± 2.6) to the end of the finishing period (17.0 ± 2.8). The prevalence of severe tail lesions was zero in the start of the finishing period, increased to the middle of the finishing period (4.5 ± 1.7) and decreased to the end of the finishing period (1.3 ± 0.9).

Table 3. Statistical analysis of the effect of density, time and the interaction between density and time, on behavior variables

	Density		Time		Density x Time	
Variables %	**$F_{1,92}$**	**P-value**	**$F_{2,92}$**	**P-value**	**$F_{2,92}$**	**P-value**
Fearful	2.91	0.0914	18.45	<.0001	9.60	0.0002
Contact seeking	0.06	0.8122	78.13	<.0001	3.58	0.0320
Tail down	5.76	0.0184	1.17	0.3156	1.89	0.1572
Curled tail	0.06	0.8071	3.29	0.0418	3.88	0.0240
Tail wagging	16.84	<.0001	7.81	0.0007	6.60	0.0021
Lameness	0.59	0.4443	4.46	0.0141	0.37	0.6922
Hernia	1.45	0.2309	1.17	0.3161	1.46	0.2374
Minor lesions ear	23.51	<.0001	57.56	<.0001	6.36	0.0026
Severe lesions ear	0.18	0.6744	142.41	<.0001	3.13	0.0486
Total lesions ear	34.71	<.0001	598.58	<.0001	27.25	<.0001
Minor lesions body	0.26	0.6088	75.03	<.0001	11.30	<.0001
Severe lesions body	1.33	0.2524	41.19	<.0001	0.87	0.4208
Total lesions body	5.35	0.0230	424.64	<.0001	19.51	<.0001
Minor lesions tail	17.88	<.0001	5.75	0.0044	10.10	0.0001
Total lesions tail	28.88	<.0001	0.88	0.4190	12.27	<.0001

Table 4. Average prevalence of behavior both density groups and all three time points (mean ± SE)

	Density		Time		
	1.5m²/pig	**1.0m²/pig**	**Start**	**Middle**	**End**
Variables (%)	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**
Fearful	10.1 ± 3.4	1.9 ± 1.0	17.3 ± 5.9	0.8 ± 0.8	0.0 ± 0.0
Contact seeking	53.5 ± 6.2	54.9 ± 4.1	26.2 ± 6.5	65.1 ± 5.7	71.4 ± 3.4
Tail down	4.8 ± 1.9	11.3 ± 3.4	9.2 ± 3.0	9.2 ± 3.3	5.9 ± 1.7
Curled tail	87.5 ± 3.0	86.8 ± 3.7	89.1 ± 3.3	82.5 ± 4.5	90.0 ± 2.4
Tail wagging	7.7 ± 2.5	1.9 ± 1.1	1.9 ± 1.1	8.4 ± 2.8	4.2 ± 1.6
Lameness	4.2 ± 1.8	5.2 ± 1.5	2.6 ± 1.4	5.4 ± 1.6	6.2 ± 1.9
Hernia	2.7 ± 1.4	1.1 ± 0.8	1.6 ± 1.1	1.7 ± 1.0	2.5 ± 1.3
Minor lesions ear	33.6 ± 3.8	49.6 ± 3.6	55.4 ± 4.1	48.2 ± 4.4	21.3 ± 2.7
Severe lesions ear	16.1 ± 2.7	18.5 ± 3.2	42.0 ± 4.5	8.8 ± 3.3	1.1 ± 1.1
Total lesions ear	49.7 ± 2.4	68.1 ± 3.7	97.4 ± 1.7	57.0 ± 4.1	22.4 ± 3.4
Minor lesions body	35.1 ± 4.4	38.3 ± 5.3	59.7 ± 7.8	43.6 ± 4.3	6.8 ± 2.6
Severe lesions body	12.2 ± 3.5	18.4 ± 3.7	33.7 ± 7.3	12.2 ± 3.5	0.0 ± 0.0
Total lesions body	47.3 ± 2.2	56.7 ± 5.2	93.4 ± 3.6	55.8 ± 5.0	6.8 ± 2.6
Minor lesions tail	11.9 ± 2.7	22.8 ± 2.7	20.8 ± 2.6	14.3 ± 2.8	17.0 ± 2.8
Severe lesions tail	0.9 ± 0.5	2.9 ± 1.2	0 ± 0	4.5 ± 1.7	1.3 ± 0.9
Total lesions tail	12.8 ± 2.8	25.7 ± 2.6	20.8 ± 2.6	18.9 ± 2.7	18.3 ± 2.9

Table 5. Average prevalence of behavior at each time for both density groups (mean ± SE)

	Lower-density pens (1.5m^2/pig)			Higher-density pens (1.0m^2/pig)		
Time	**Start**	**Middle**	**End**	**Start**	**Middle**	**End**
Variables (%)	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**	**$\bar{X}$ ± SE**
Fearful	29.5 ± 9.3	0.9 ± 0.9	0 ± 0	5.0 ± 2.4	0.6 ± 0.6	0 ± 0
Contact seeking	20.5 ± 7.3	70.5 ± 7.0	69.6 ± 4.3	31.9 ± 5.6	59.7 ± 4.3	73.1 ± 2.5
Tail down	4.5 ± 1.7	4.5 ± 2.2	5.4 ± 1.8	13.8 ± 4.3	13.9 ± 4.3	6.3 ± 1.6
Curled tail	93.8 ± 2.2	81.3 ± 4.3	87.5 ± 2.6	84.4 ± 4.3	83.6 ± 4.6	92.4 ± 2.1
Tail wagging	1.8 ± 1.2	14.3 ± 4.1	7.1 ± 2.3	1.9 ± 1.0	2.5 ± 1.4	1.3 ± 0.9
Lameness	2.7 ± 1.4	4.5 ± 1.7	5.4 ± 2.2	2.5 ± 1.4	6.3 ± 1.5	6.9 ± 1.5
Hernia	1.8 ± 1.2	2.7 ± 1.4	3.6 ± 1.6	1.3 ± 0.9	0.6 ± 0.6	1.3 ± 0.9
Minor lesions ear	52.7 ± 5.2	41.1 ± 4.5	7.1 ± 1.8	58.1 ± 2.9	55.3 ± 4.3	35.4 ± 3.5
Severe lesions ear	44.6 ± 5.4	3.6 ± 2.6	0 ± 0	39.4 ± 3.6	14.0 ± 3.9	2.1 ± 2.1
Total lesions ear	97.3 + 1.4	44.7 ± 3.9	7.1 ± 1.8	97.5 ± 1.9	69.3 ± 4.3	37.5 ± 5.0
Minor lesions body	68.8 ± 7.6	33.0 ± 3.6	3.6 ± 2.1	50.6 ± 8.0	54.2 ± 5.0	10.0 ± 3.0
Severe lesions body	28.6 ± 7.3	8.0 ± 3.2	0 ± 0	38.8 ± 7.2	16.4 ± 3.8	0 ± 0
Total lesions body	97.4 ± 1.2	41.0 ± 3.4	3.6 ± 2.1	89.4 ± 5.9	70.6 ± 6.6	10.0 ± 3.0
Minor lesions tail	19.6 ± 2.6	8.9 ± 2.6	7.1 ± 2.9	21.9 ± 2.6	19.6 ± 2.9	26.9 ± 2.7
Severe lesions tail	0 ± 0	2.7 ± 1.4	0 ± 0	0 ± 0	6.3 ± 3.0	2.5 ± 1.7
Total lesions tail	19.6 ± 2.6	11.9 ± 3.0	7.1 ± 2.9	21.9 ± 2.6	25.8 ± 2.4	29.4 ± 2.8

3.3 The effect of interaction of density and time on behavior and welfare

The interaction of stocking density and time had a significant effect on fearful behavior and contact seeking behavior, curled tail, tail wagging, minor ear lesions, severe ear lesions, total ear lesions, minor body lesions, total body lesions, minor tail lesions and total tail lesions (Table 2). The interaction did not have a significant effect on the prevalence of tail down, lameness, hernia, or severe body lesions.

3.3.1 Fearful behavior

In the start of the finishing period, fearful behavior was significantly more prevalent in lower-density pens (1.5 m^2/pig) (29.5 ± 9.3), compared to higher-density pens (1.0 m^2/pig) (5.0 ± 2.4) (Table 2; Table 5). In the middle and end of the finishing period, there was a significant decrease in fear responses for both groups (Figure 4). In the end of the finishing period, none of the pigs showed fearful behavior.

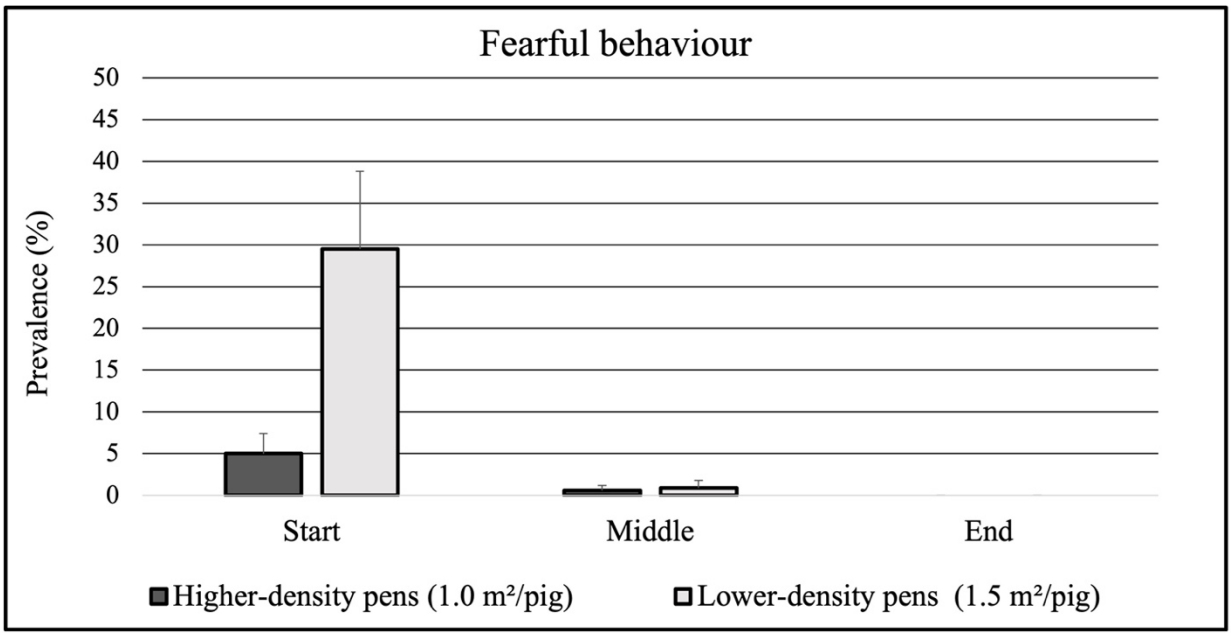

Figure 4. Interaction effect of density and time; mean + SE on the prevalence of fear behavior

3.3.2 Contact seeking behavior

Contact seeking behavior was significantly increasing, in both density groups, from the start of the finishing period to the middle of the finishing period (Table 3). Contact seeking behavior increased more from the start to the middle of the finishing period in the lower-density pens (1.5 m^2/pig), compared with the higher-density pens (1.0 m^2/pig) (Figure 5). In the start of the finishing period, contact seeking behavior was more prevalent in the higher-density pens (1.0 m^2/pig) (31.9 ± 5.6), than the lower-density pens (1.5 m^2/pig) (20.5 ± 7.3). In the higher-density pens (1.0 m^2/pig), the contact seeking behavior was steadily increasing throughout the finishing period, whereas in the lower-density pens (1.5 m^2/pig), it stabilized in the middle of the finishing period (Table 5).

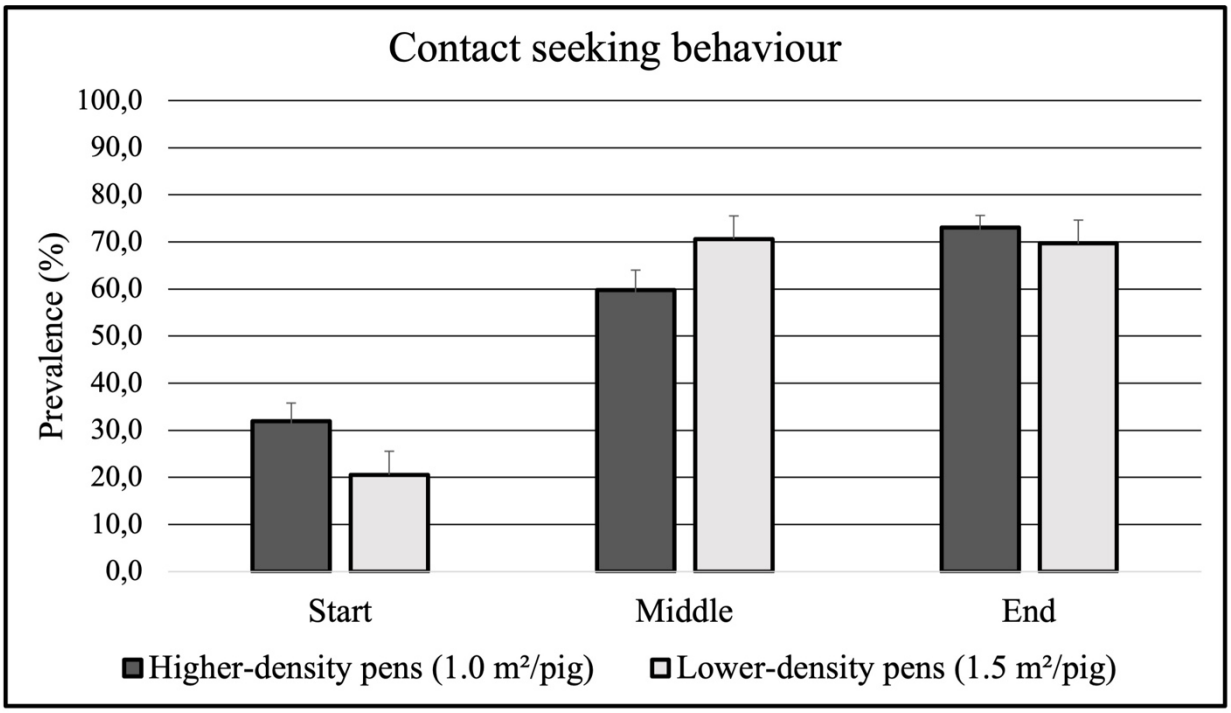

Figure 5. Interaction effect of density and time; mean + SE on the prevalence of contact seeking behavior

3.3.3 Curled tail

The interaction between stocking density and time had a significant effect on the prevalence of curled tail (Table 3). As presented in Figure 6, in lower-density pens (1.5 m^2/pig) the prevalence of curled tail started at a higher level (93.8 ± 2.2) compared to the higher-density pens (1.0 m^2/pig) (84.4 ± 4.3). In both density groups, this amount decreased towards the middle of the finishing period. In the end of the finishing period, the higher-density pens (1.0 m^2/pig) had a slightly higher prevalence of pigs with curled tail (92.4 ± 2.1) compared to the lower-density pens (1.5 m^2/pig) (87.5 ± 2.6) (Table 5).

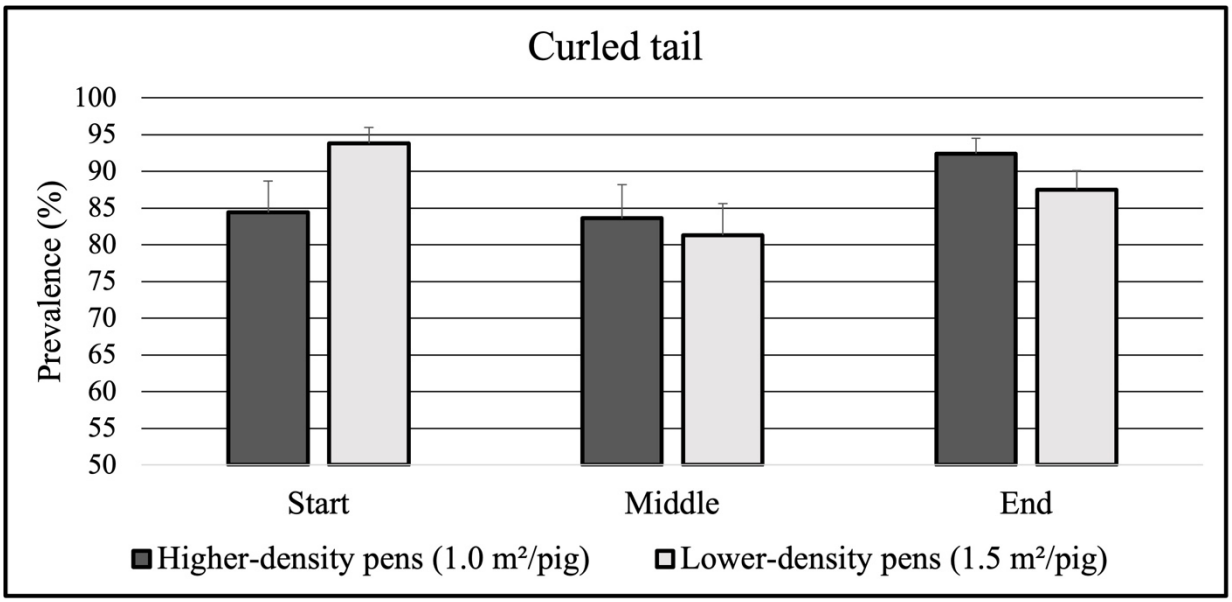

Figure 6. Interaction effect of density and time; mean + SE on the prevalence of curled tail

3.3.4 Tail wagging

The interaction between animal stocking density and time had a significant effect on the proportion of pigs with tail wagging (Table 3). As presented in Figure 7, both density groups had a low prevalence of tail wagging in the start of the finishing period. In the middle of the finishing period, the lower-density group (1.5 m^2/pig) had a significantly higher prevalence of tail wagging (14.3 ± 4.1), compared to the higher-density group (1.0 m^2/pig) (2.5 ± 1.4). In the end of the finishing period, the prevalence of tail wagging had decreased for both density groups, but was still higher in the lower-density group (1.5 m^2/pig) (7.1 ± 2.3) compared to the higher-density group (1.0 m^2/pig) (1.3 ± 0.9) (Table 5).

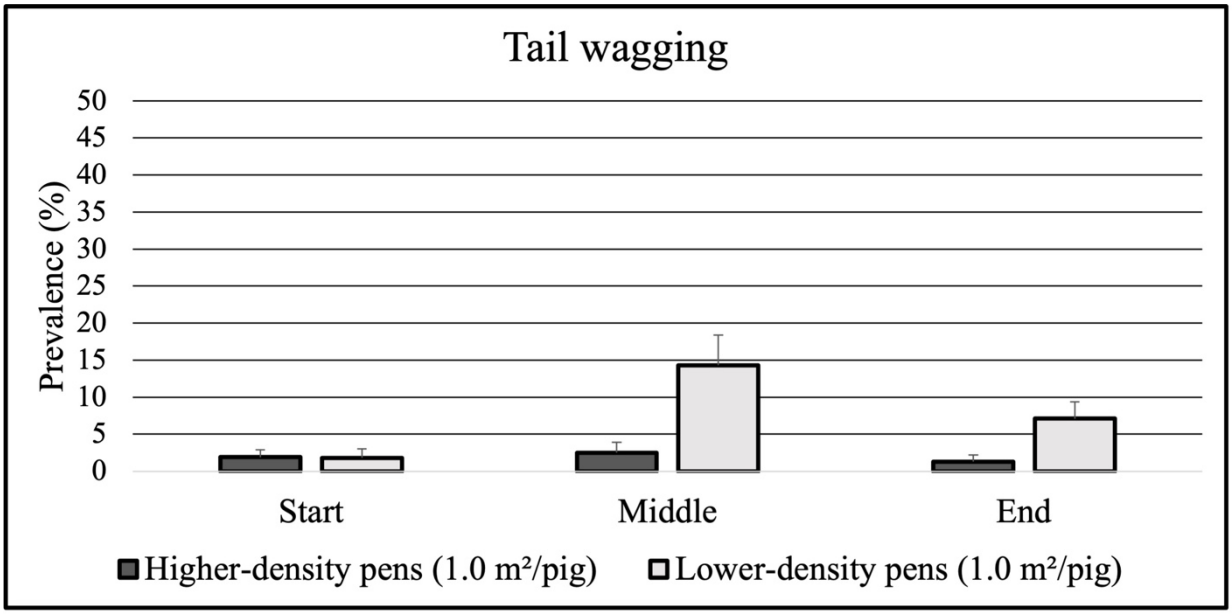

Figure 7. Interaction effect of density and time; mean + SE on the prevalence of tail wagging

3.3.5 Ear lesions

The interaction between stocking density and time had a significant effect on the prevalence of minor, severe and total ear lesions (Table 3). The prevalence of minor ear lesions was lower in the lower-density pens (1.5 m^2/pig) (52.7 ± 5.2) compared to the higher-density pens (1.0 m^2/pig) (58.1 ± 2.9). In the start of the finishing period, the prevalence of severe ear lesions was higher in the lower-density pens (1.5 m^2/pig) (44.6 ± 5.4) compared to the higher-density pens (1.0 m^2/pig) (39.4 ± 3.6). In the end of the finishing period, the prevalence of severe ear lesions was zero in the lower-density pens (1.5 m^2/pig), and 2.1 ± 2.1 in the higher-density pens (1.0 m^2/pig). The prevalence of total ear lesions was approximately 97% for both density groups at the start of the finishing period and decreased significantly over time for both groups (Figure 8). In the end of the finishing period, the prevalence of total ear lesions was significantly lower in the lower-density pens (1.5 m^2/pig) (7.1 ± 1.8), compared to the higher-density pens (1.0 m^2/pig) (37.5 ± 5.0) (Table 5).

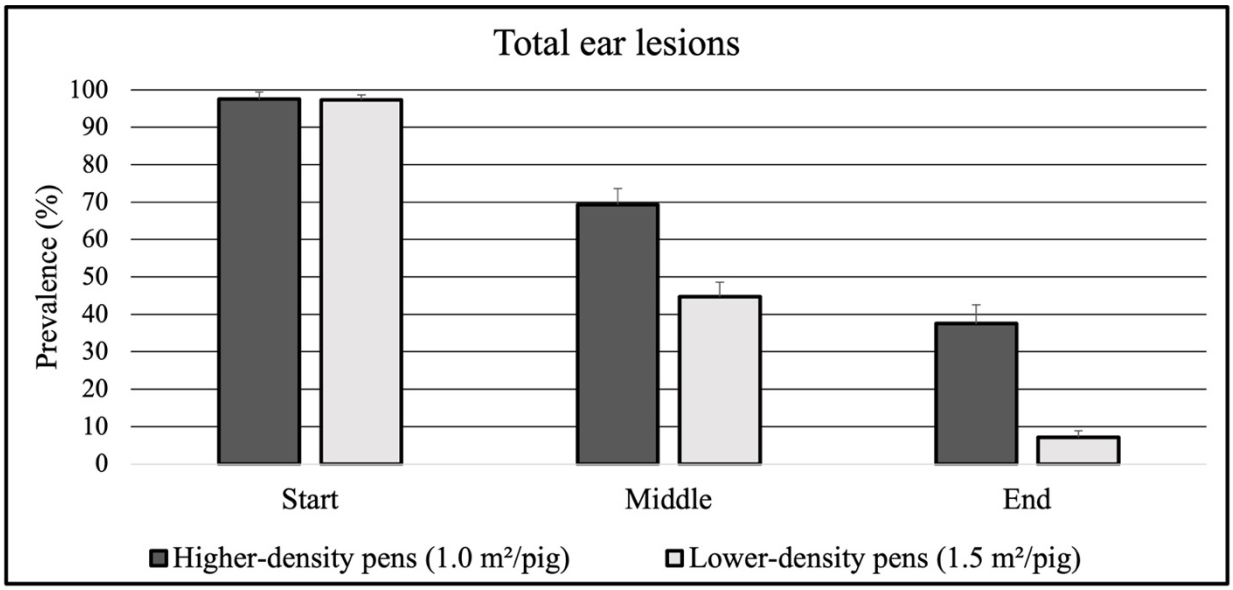

Figure 8. Interaction effect of density and time; mean + SE on the prevalence of ear lesions

3.3.6 Body lesions

The interaction between stocking density and time had a significant effect on the prevalence of minor and total body lesions (Table 3). The prevalence of minor body lesions was lower higher in the lower-density pens (1.5 m^2/pig) in the start of the finishing period (68.8 ± 7.6), compared to the higher-density pens (1.0 m2) (50.6 ± 8.0). By the middle of the finishing period, the prevalence of minor body lesions had decreased to 33.0 ± 3.6 in the lower-density pens (1.5 m^2/pig). In the higher-density pens (1.0 m^2/pig) the prevalence of minor body lesions was still high, 54.2 ± 5.0. At the end of the finishing period, minor body lesions were significantly more prevalent in the lower in the higher-density pens (1.0 m^2/pig) (10.0 ± 3.0) compared to the lower-density pens (1.5 m^2/pig) (3.6 ± 2.1). As presented in Figure 9, the prevalence of total body lesions is similar in the start of the finishing period, and significantly decreases over time for both density groups. The decrease in total body lesions is more rapid in lower-density pens (1.5 m^2/pig) compared to higher-density pens (1.0 m^2/pig).

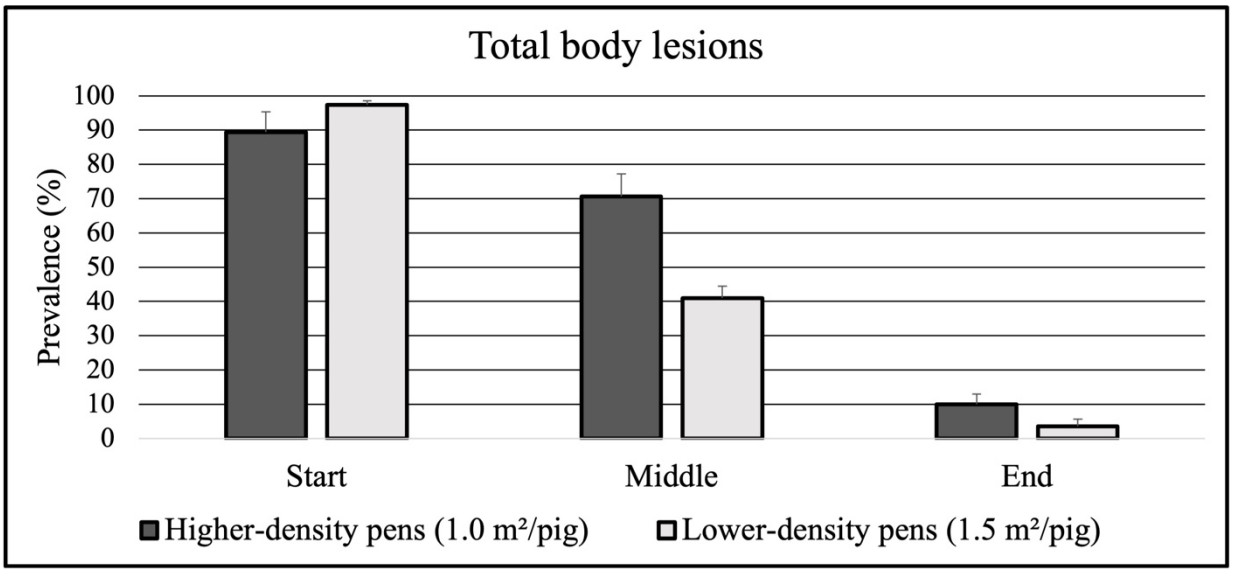

Figure 9. Interaction effect of density and time; mean + SE on the prevalence of body lesions

3.3.7 Tail lesions

The interaction between animal stocking density and time had a significant effect on the prevalence of minor and total tail lesions (Table 3). In the start of the finishing period, the prevalence of minor tail lesions was similar in both density groups. The prevalence of minor tail lesions significantly decreases in the lower-density pens (1.5 m^2/pig) from 19.6 ± 2.6 in the start of the finishing period, to 7.1 ± 2.9 in the end of the finishing period. The prevalence of minor tail lesions significantly increases from the middle (19.6 ± 2.9) to the end (26.9 ± 2.7) of the finishing period in the higher-density pens (1.0 m^2/pig).

As presented in Figure 10, the occurrence of total tail lesions also starts out at a similar level in both groups. The prevalence is significantly decreasing throughout the finishing period in the lower-density pens (1.5 m^2/pig) and increasing throughout the finishing period in the higher-density pens (1.0 m^2/pig) (Table 5). In the end of the finishing period, the prevalence of total tail lesions was higher in higher-density pens (1.0 m^2/pig) (29.4 ± 2.0), compared to the lower-density pens (1.5 m^2/pig) (7.1 ± 2.9).

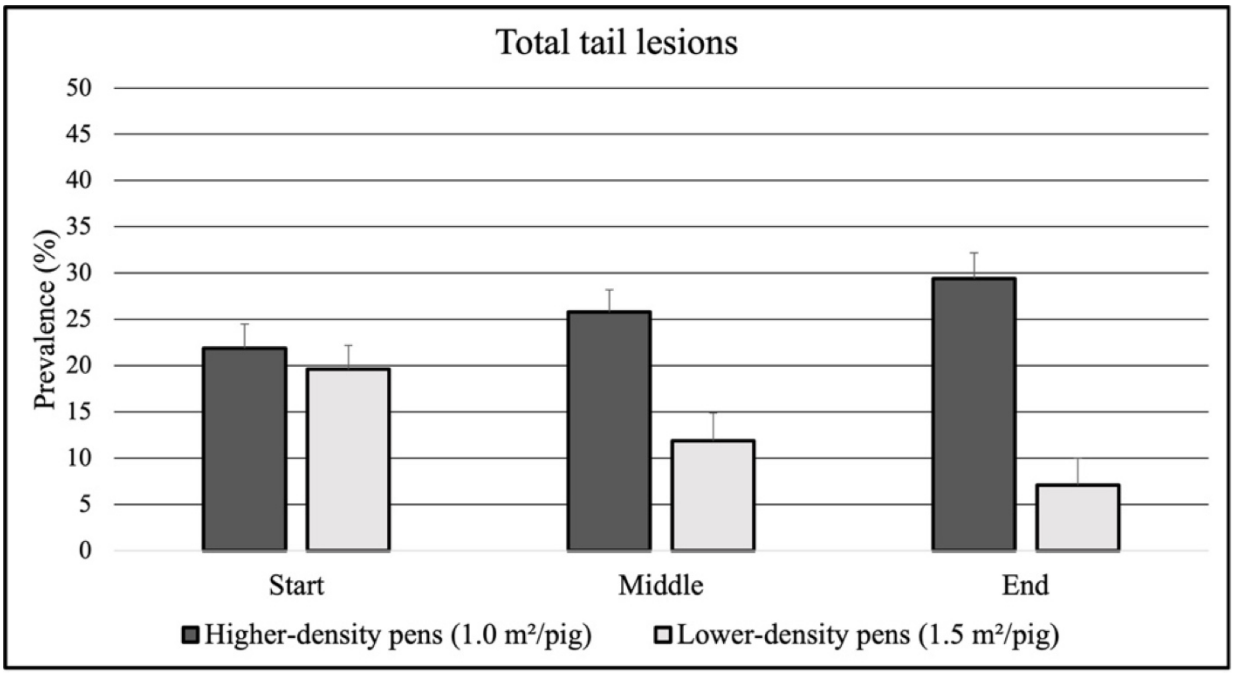

Figure 10. Interaction effect of density and time; mean + SE on the prevalence of tail lesions

3.4 Production variables

Table 6. Statistical analysis of the effect of density and sex on production and carcass traits

	Density		Sex	
Variables	**$F_{1,224}$**	**P-value**	**$F_{1,224}$**	**P-value**
Slaughter weight (kg)	0.45	0.5034	7.10	0.0083
Meat percentage (%)	0.06	0.8125	27.67	<.0001
Daily growth (grams)	1.08	0.3002	0.66	0.4164

3.4.1 The effect of density on production variables

Stocking density had no significant effect on any of the production variables regarding growth performance (slaughter weight and daily growth) or meat percentage (Table 6). Mean, standard error and range (min-max) for production variables based on density is presented in Table 7.

Table 7: Average prevalence (mean ± SE) and range (min-max) for the production variables based on density

	Lower-density pens ($1.5m^2$/pig)		Higher-density pens ($1.0m^2$/pig)	
Variables	**$\bar{X}$ ± SE**	**Min - max**	**$\bar{X}$ ± SE**	**Min - max**
Slaughter weight (kg)	93.0 ± 0.6	81.7 - 113.1	92.5 ± 0.5	72.7 - 109.1
Meat percentage (%)	60.3 ± 0.2	55 - 64	60.4 ± 0.1	55 - 65
Daily growth (grams)	1224 ± 9.6	954 - 1476	1208 ± 7.5	892 - 1430

3.4.2 Effect of density on feed efficiency

FCR is an indicator of the number of feed units (FE_n) needed for 1 kg weight gain. One feed unit is equivalent to the NE (net energy) contained in 1 kg of barley, or 8.8 MJ (Svineportalen, 2022). Mean, standard error and range for feed efficiency is presented in Table 8.

Table 8: Average prevalence (mean ± SE) and range (min-max) for feed efficiency based on density

	Lower-density pens (1.5m^2/pig)		**Higher-density pens (1.0m^2/pig)**	
Variables	**$\bar{X}$ ± SE**	**Min - max**	**$\bar{X}$ ± SE**	**Min - max**
FCR	2.58 ± 0.02	2.46 – 2.72	2.59 ± 0.01	2.49 – 2.67
Kg feed/pig (whole period)	241.43 ± 3.09	218.94 – 264.65	240.97 ± 1.03	234.95 – 246.67
Kg feed/kg weight gain	2.35 ± 0.02	2.24 – 2.47	2.35 ± 0.01	2.27 – 2.43

3.4.3 The effect of sex on production variables

Sex had a significant effect on slaughter weight and meat percentage (Table 6). The female pigs had a significantly higher slaughter weight (93.8 ± 0.5) than the male pigs (91.8 ± 0.6). The female pigs also had a significantly higher meat percentage (61.0 ± 0.1) than the male pigs (59.8 ± 0.1) There was no significant effect of sex on daily growth (Table 6).

Table 9: Average prevalence (mean ± SE) and range (min-max) of the production and carcass traits for both sexes

	Male		Female	
Variables	**$\bar{X}$ ± SE**	**Min-max**	**$\bar{X}$ ± SE**	**Min-max**
Slaughter weight (kg)	91.8 ± 0.6	78.6 – 107.7	93.8 ± 0.6	72.7 – 113.1
Meat percentage (%)	59.8 ± 0.1	55 - 64	61.0 ± 0.1	57 - 65
Daily growth (grams)	1221 ± 9.1	954 - 1790	1210 ± 8.9	892 - 1476

3.4.4 The effect of feed type on production variables

Feed type had no significant effect on slaughter weight, meat percentage or daily growth. There was no difference between the two feed type groups in any production variables.

3.5 Animal and pen cleanliness

In approximately 75% of the cases, the cleanliness of the pen was at the highest score, meaning that less than 10% of the solid floor area was wet or covered with manure. The rest of the time, cleanliness pen score was second best, meaning that between 10-40% of the solid floor was wet or covered with manure. There was no difference between the two density groups considering how clean the pens were.

98% of the pigs achieved the highest score possible on cleanliness pigs, meaning that less than 10% of the body was covered with manure. There was no difference between the two density groups considering how clean the pigs were.

4.0 Discussion

4.1 Overview

The aim of this study was to investigate the effect of decreased stocking density on animal welfare in Norwegian finishing pigs. To avoid the negative consequences of high animal density, such as poor animal welfare and increased prevalence of disease expression (EFSA, 2005), most countries require a minimum space allowance, which varies depending on the size of the animals. In the EU, the minimum space allowance per pig is 0.65 m^2 for finishing pigs up to 110 kg (Wageningen, 2010). In Norway, the minimum space allowance for pigs up to 110 kg is 0.80 m^2. The Finnish animal welfare regulations are the most conservative in Europe, requiring 0.90 m^2 per pig for pigs up to 107 kg. The pigs in both experimental groups had notably more space than required by both Norwegian and Finnish animal welfare regulations.

4.2 Welfare variables

4.2.1 Fearful behavior

The difference in fear responses between the two groups is only significant in the start of the finishing period. At this time, the prevalence of fear responses was high in both groups due to being in a brand new physical and social environment, as they had arrived at the farm just one day prior. Contrary to our hypothesis, the prevalence of fear responses was higher in the lower-density pens. As the fear-test only registered whether the pigs fled or not when a researcher entered the pen, one possible explanation for this result is that the pigs in the lower-density pens had more room to express fearfulness in the way they were inclined to, whereas the pigs in the higher-density pens did not have room to flee.

4.2.2 Contact seeking behavior

Contact seeking behavior increased significantly throughout the finishing period, with the most significant increase between the beginning and the middle of the finishing period. This effect is expected, as the pigs are growing more used to being handled by people and they

have established a social hierarchy in the pen over time. The interaction of density and time also had a significant effect on contact seeking behavior, with the contact seeking behavior in the lower-density group increasing faster than in the higher-density group. A study by Turner et al. (2021), demonstrates that a reduction in space allowance from 1.97 m^2 to 0.98 m^2 per pig caused an increase in the levels of the stress hormone cortisol. The lower overall stress levels of the pigs in the lower-density pens might explain why they become contact seeking more rapidly. Contrary to our hypothesis, density alone had no significant effect on contact seeking behavior. This indicates that pigs in both groups experienced their environment as secure.

4.2.3 Tail indicators

In agreement with our hypothesis, the pigs in the lower-density pens (1.5 m^2/pig) had significantly higher prevalence of tail wagging, and conversely, tail down was significantly more frequent in the higher-density pens (1.0 m^2/pig). Curled tail and tail wagging were also significantly affected by time. Tail wagging was low in the start of the finishing period, higher in the middle, and decreased at the end of the finishing period. Curled tail was high in the start and end of the finishing period but decreases in the middle of the finishing period. This decrease corresponds with the increase in tail wagging and is not indicative of lower animal welfare in the middle of the finishing period. The same effect can be seen in the interaction effect, both experimental groups had a slight decrease in curled tail in the middle of the finishing period, due to an increase in tail wagging. The highest prevalence of tail wagging was in the lower-density pens (1.5 m^2/pig) in the middle of the finishing period. This might be explained by the fact that at this time point, the pigs have formed a stable social dynamic and they have sufficient floor space per pig. Towards the end of the finishing period, tail wagging decreases in both groups, which might correspond with the pens becoming more crowded as the pigs grow bigger. According to Camerlink and Ursinus (2020) tail wagging is a reliable indicator of contentment, and research shows that pigs will wag while playing, during contact with familiar handlers and while having access to an enriched environment. Tail down, or the absence of a curled tail, is a reliable negative welfare indicator, as pigs will curl or wag their tail when experiencing positive emotions, such as curiosity and joy (Ocepek et al., 2020).

4.2.4 Ear, body, and tail lesions

For the purpose of this discussion, we are assuming that ear, body, and tail lesions are a result of ear, body, and tail biting.

The total amount of ear lesions (minor and severe) was significantly affected by density, time, and the interaction between density and time. The prevalence of ear lesions was higher in the higher-density pens (1.0 m^2/pig) than in the lower-density pens (1.5 m^2/pig). A study by Blömke et al. (2020) found that because ear biting occurs when the pigs' environment is unable to meet their physiological and behavioral needs ear lesions can serve as a reliable indicator of poor animal welfare. The prevalence of ear lesions started at 97% at the start of the finishing period, decreased significantly over time and was only 22% at the end of the finishing period. Because of the change in environment, there was a high amount of social stress at the start of the finishing period before group dynamics stabilize and a social hierarchy was established. When pigs are unable to cope with their environment, they have an increased risk of abnormal behaviors such as aggressiveness, which might lead to lesions on other pigs in the pen (Diana et al., 2019). Having a stable social and physical environment contributes to a more harmonious social dynamic, which might explain the low prevalence of ear lesions at the end of the finishing period. There was also a significant interaction effect between time and density. The decrease in ear lesions was significantly more rapid in the lower-density pens (1.5 m^2/pig) compared to the higher-density pens (1.0 m^2/pig). By the end of the finishing period, only 7.1% of pigs in the lower-density pens (1.5 m^2/pig) had ear lesions, whereas 37.5% of the pigs in the higher-density pens (1.0 m^2/pig) had lesions.

The prevalence of total body lesions (minor and severe) was significantly affected by density, time, and the interaction between density and time. A study by Fu et al. (2015) found that body lesions were more frequent in the groups of high density compared to those of lower density. This corresponds with the findings in our study, which showed a significantly higher prevalence of body lesions in the higher-density pens (1.0 m^2/pig). This might have the same explanation as the increased prevalence of ear lesions in the higher-density pens, which is that aggression is more prevalent in environments that are unable to meet the pigs' physiological and behavioral needs (Diana et al., 2019). In the start of the finishing period, the prevalence of body lesions was high, over 93%. It decreased throughout the finishing period, and in the end of the finishing period the prevalence was around 7%. This can be

explained by the same changes in social dynamics that might cause ear biting, as explained above. There was also a significant interaction effect between time and density. There was a higher prevalence of body lesions in the lower-density pens (1.5 m^2/pig) in the start of the finishing period compared to the higher-density pens (1.0 m^2/pig), but the prevalence was high in both density groups. The prevalence decreased at a higher rate in the lower-density pens (1.5 m^2/pig), compared to the higher-density pens (1.0 m^2/pig). In the middle of the finishing period, the prevalence had decreased to 41% in the lower-density pens (1.5 m^2/pig), compared to 71% in the higher density pens (1.0 m^2/pig). In the end of the finishing period, the prevalence was low in both groups, but still significantly higher in the higher-density pens. According to EFSA (2007), a lack of space creates a stressful environment for the pigs, which lowers the threshold for aggression.

The prevalence of total tail lesions (minor and severe) was significantly affected by density and the interaction between density and time, but not significantly affected by time. The prevalence of tail biting is known to increase with stocking density and presents a serious animal welfare problem (Brandt et al., 2020). Pigs with tail lesions have increased risk of infections, decreased growth rate as well as painful wounds on their tails (European Food Safety Authority, 2007). Even though not every pig in a pen will experience tail biting, it is indicative of poor overall welfare in the pen (Wedin et al., 2018). There were significantly more tail lesions in the higher-density pens. In the lower-density pens (1.5 m^2/pig), the prevalence of tail lesions significantly decreased over time from 19.6% at the start of the finishing period, to 7.1% in the end of the finishing period. In higher-density pens (1.0 m^2/pig), the prevalence significantly continued to increase over time as the prevalence went from 21.9% at the start of the finishing period to 29.4% at the end of the finishing period. Tail biting tends to become more frequent as the pigs grow bigger, as the pen is getting more crowded (EFSA, 2007). This is in accordance with a study by Heinonen et al. (2021), which claims that there is a definite correlation between increased space allowance and decreased prevalence of tail biting. The changes in tail lesions over time was not significant, this is because tail lesions increase in the lower-density pens (1.5 m^2/pig) and increases in the higher-density pens (1.0 m^2/pig), and the variances in the two density groups cancel each other out.

4.3 Production variables

One of the hypotheses in this thesis was that pigs in lower-density pens (1.5 m^2/pig) would have a higher growth rate due to better overall welfare and a less stressful environment compared to pigs in higher-density pens (1.0 m^2/pig). One of the Norwegian pig farmers who participated in "Griseløftet", mentions in an article that he believes that keeping pigs in lower-density pens has a positive impact on the feed usage on his farm. He decreased the stocking density on his farm by reducing the number of animals in each pen from 11 to 9 individuals. The motivation behind this measure was a zero-vision on tail lesions in addition to decreasing feed usage (Svineportalen, 2022). However, the results show no significant effect of density on any of the production variables (slaughter weight, meat percentage, and daily growth). This corresponds to a Finnish study by Valros et al. (2021), who found that growth rate in Finnish pigs is comparable with the growth rate in other European pigs, despite the stricter space allowance requirements in Finland. This can perhaps be explained by the fact that the pigs in lower-density pens were more active, and consequently had a higher caloric requirement and therefore a lower feed efficiency than expected.

Fu et al., (2015) found that pigs in high density conditions performed less positive social behaviors and less resting, than pigs in low density conditions. They also found that pigs in high density conditions more often had high body temperature, which is an indicator of inflammatory response. All these factors might contribute to lower feed efficiency in high density conditions. The fact that there was no significant difference in either feed efficiency or growth rate might mean either that there is no difference between the two groups, or that the increased caloric demand due to increased activity in the lower-density group (1.5 m^2/pig) might equal the increased caloric demand due to stress or inflammation in the higher-density group (1.0 m^2/pig), and so the differences cancel each other out.

The only factor that had a significant effect on the production variables was sex. Slaughter weight and meat percentage was significantly affected by the sex of the pigs. There was a significantly higher slaughter weight in female pigs than in male pigs. The male pigs had a significantly higher meat percentage compared to the female pigs. There was no significant effect of feed type on any of the production variables.

4.4 Limitations

4.4.1 Inter-observer reliability

The registrations were conducted at three times by several different people. This represents a possible limitation regarding the inter-observer reliability of the research. A behavioral category cannot be recorded reliably unless it is clear and unambiguously defined (Bateson & Martin, 2021). The welfare protocol included descriptions of each measurement, but to ensure inter-observer reliability, the welfare protocol should be so precise that there is no room for interpretation. In the welfare protocol used in this study, the definition of each parameter varied slightly with each observer's perception, meaning the data collected is not necessarily reliable. To ensure repeatability, the welfare protocol should have had perfectly unambiguous descriptions of each parameter, including pictures or illustrations of the categories of cleanliness, amount of bedding, and lesions.

4.4.2 Observer bias

This was not a blinded study, meaning that the observer knew which experimental group they were observing at the time of observation, which means that the observer might have subconsciously been influenced by the hypothesis.

4.4.3 Validity of the fear-test

Validity refers to whether a metric actually measures what it is designed to measure. The fear-test used in this study was conducted by several different people, at three different times. The fear-test is complicated to standardize due to the researchers using their presence in the pens as the catalyst for fear responses. The researchers necessarily differed in size, demeanor, and scent, and so it is impossible to say if the variations in fear responses are due to the pigs generally feeling safe or unsafe, or the pigs experiencing the presence of one particular researcher as safe or unsafe.

4.4.4 Validity of the tail indicators

Another flaw in the experimental design is the definitions of the tail indicators in the welfare protocol. Curled tail and tail wagging are two positive welfare indicators that are not mutually exclusive in practice, but in this study, we only registered one or the other. Tail wagging occurs for a brief period of time and should be classified as an event, while curled tail is a behavior of longer duration and should be classified as a state (Bateson and Martin, 2021). A clear definition of categories of behavior is paramount to a valid experimental design, and juxtaposing states and events should be avoided.

4.4.5 Validity of the density parameter

Because the differences in density are achieved by changing the number of individuals in each pen, there are variations in both group size and stocking density in the two groups. Changes in group size can affect the social environment in each pen, and larger group sizes can cause negative social behavior in finishing pigs. (Meyer-Hamme, 2016). Since we were unable to control for group size, it is impossible to determine with certainty whether the significant differences in welfare parameters are due to the group size in each group or the density in each group. A better way to isolate the effect of changes in the stocking density, would be to have different sized pens with the same number of individuals in each. In such an experiment, the results would unquestionably be due to the changes in stocking density.

4.5 Practical implications

For most pig farmers with established farms, it would be an enormous financial investment to rebuild their pens to abide by potential new animal welfare regulations. It is a more viable option to have fewer individuals in each pen, and thereby reduce the stocking density. That way the farmers have a relatively easy and cost-effective possibility to increase the animal welfare and comply with potential new regulations, without having to re-build their housing facilities.

The results from this study show that decreasing the animal stocking density by reducing the number of pigs in each pen will improve animal welfare. Further research needs to be done to

determine how much floor space per pig is optimal to maintain good animal welfare. In both the conditions in this study, the pens were crowded towards the end of the finishing period, and we might have seen a more definite difference in the two groups if the density in the lower-density pens (1.5 m^2/pig) had been much lower than the density in the higher-density pens (1.0 m^2/pig).

A study conducted in China by Fu et al. (2015) compared stocking density of 0.8 m^2, 1.2 m^2 and 1.6 m^2 per pig. The researchers concluded that the optimal stocking density considering both animal welfare and the building utilization in current conditions was 1.2 m^2 per pig. The results showed that pigs housed at a lower stocking density performed more social behavior and had less lesions, compared to those housed at higher stocking density. This is supported by several previous studies, showing that as stocking density increases, the amount of negative social behavior gradually increases, such as aggression.

Regardless of the density in the pens, the physical environment in the pens is barren and monotonous, and the concrete floors and artificial lighting is not optimal for animal welfare. Animal stocking density is only one of many aspects of animal welfare that needs to be considered when making new regulations.

5.0 Conclusion

Reducing animal stocking density by increasing floor space allowance per animal significantly improved the animal welfare of the pigs in this study. Pigs in pens with lower density had significantly higher prevalence of pigs with tail wagging, and significantly lower prevalence of pigs with tail down. The total amount of ear, body, and tail lesions were lower in lower-density pens. The most significant finding is the interaction effect between time and density on tail lesions, where our data showed a decrease in tail lesions over time in lower density pens and an increase in tail lesions over time in the higher-density pens . In this study, stocking density was found to no significant effect on production variables.

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