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– en studie inom svensk smågrisproduktion

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Abstract

Natural weaning of piglets occurs gradually and finalises between 14-17 weeks of age. In 2017, Swedish pig production faced changes in national regulations regarding weaning procedures. The new regulations implemented a decrease of weaning age from 28 days of age to 21 days of age for a maximum of 10 % of piglets in each batch. The change of regulations derived from a pilot study suggesting that a decrease in weaning age would increase productivity. The pilot study also suggested that the late weaning age in Swedish pig production negatively affects sow body condition due to increased litter sizes in the genetic lines used. However, this has not been confirmed in other studies. Instead, other studies suggest that the negative impact of decreased weaning age on piglets outweigh the potential positive effects on the sow. Most studies comparing differences in weaning age have been performed in other production systems than the Swedish, distinguished by loose farrowing pens with straw provisions compared with the farrowing crates used in most studies on this topic. Thereby, the knowledge on how weaning age affects piglets and sows under Swedish production conditions is lacking.

The current master thesis is a pilot study designed to map and investigate how differences in weaning age affect sows before weaning and the effects on piglets before and after weaning, aiming to increase the knowledge about the effects of different weaning ages in an environment similar to Swedish production systems. The study compared three groups with different weaning ages; 3 (n=7 litters), 4 (n=6 litters), and 5 (n=6 litters) weeks and contained both scan sampling and continuous recording of sow and piglet behaviour from 14 days of age up until 44 days of age. The behavioural recording was performed two days per week, on day 1 and 3 of each week. Scans were collected once per hour between 07:00 and 20:00, while continuous recording was performed three times per day (09:00, 13:00, 17:00) for five minutes each. Sow weight and backfat thickness were collected in connection to farrowing and weaning. Piglet growth was collected between farrowing and nine weeks of age.

The results of this study indicate that piglets weaned at 21 days of age spend more time standing up, eating solid food, fighting, belly nosing and mounting after weaning than piglets weaned at 35 days of age. Piglets weaned at 28 days of age were belly nosing more after weaning than those weaned at 35 days of age. Piglets weaned at 21 days of age had a significantly higher growth rate between 28 days and 9 weeks of age than piglets weaned on days 28 and 35. Regarding the sows, there were no statistically significant results found on behaviour, weight or backfat thickness. However, the descriptive statistics show that sows weaned from their piglets on day 35 had less backfat than those weaned on days 28 and 21. They also showed that sows spent less time having snout contact with the piglets and laid down less the longer they stayed with the piglets. Since this is a pilot study, the results found should be interpreted with caution. However, the results show a need for further research to confirm whether these findings apply to larger populations.

Keywords: piglet, sow, weaning age, behaviour, growth

Sammanfattning

Avvänjning av smågrisar sker naturligt mellan 14 och 17 veckors ålder, medan avvänjning vanligtvis sker mellan 3 och 4 veckors ålder inom smågrisproduktionen. Under 2017 presenterades förändringar i svensk lagstiftning gällande avvänjningsåldrar. Den nya lagstiftningen gjorde gällande att 10 % av smågrisar i en omgång kan avvänjas vid 21 dagars ålder till skillnad från den tidigare gränsen på 28 dagars ålder. Dessa förändringar härrör från en pilotstudie som föreslog att en tidigarelagd avvänjning resulterade i ökad produktivitet. Pilotstudien menade också att avvänjning vid 28 dagars ålder påverkar suggans vikt negativt på grund av den ökade totalvikten hos smågrisarna i respektive kull. Dessa faktorer har dock inte bekräftats i andra studier. I stället har andra studier föreslagit att de negativa effekter som en tidigarelagd avvänjningsålder har på smågrisar överväger de negativa effekter som den har på suggor. De flesta studier som jämför dessa effekter har dock utförts under andra produktionsformer än det svenska, som karaktäriseras av smågrisboxar där suggan kan röra sig fritt, till skillnad från de flesta studier där suggan är fixerad i samband med grisningen. Därför är kunskapen om hur olika avvänjningsåldrar påverkar suggan och smågrisarna i svensk smågrisproduktion begränsad, och grunderna till ändringarna i lagstiftningen behöver bekräftas.

Den här mastersuppsatsen undersöker hur olika avvänjningsåldrar påverkar suggorna fram till avvänjning och effekterna hos smågrisarna innan och efter avvänjning. Detta för att öka förståelsen för vilka effekter avvänjningsålder har i en miljö lik svensk smågrisproduktion. Studien jämförde tre grupper med olika avvänjningsåldrar; 3 (n=5), 4 (n=5) och 5 (n=6) veckor och använde både scan sampling och kontinuerliga observationer för att fånga beteenden hos suggor och smågrisar från 14 dagars ålder fram till 44 dagars ålder. Beteenderegistreringar utfördes två dagar per vecka, på dag 1 och 3 för varje vecka. Scans registrerades en gång i timmen mellan 07:00 och 20:00, medan kontinuerliga observationer genomfördes tre gånger per dag (09:00, 13:00, 17:00) under fem minuter per observation.

Resultaten av den här uppsatsen indikerar att smågrisar som avvänjs vid 21 dagars ålder spenderar mer tid åt att stå, äta fast föda, slåss, bukmassage och rida på varandra efter avvänjning än smågrisar som avvänjs vid 35 dagars ålder. Resultaten indikerar också att grisar som avvänja vid 28 dagars ålder utför mer bukmassage efter avvänjning än de som blir avvanda vid dag 35. De smågrisar som avvandes vid 21 dagars ålder växte snabbare från 28 dagars ålder fram till nio veckors ålder, än de grisar som avvandes vid 28 och 35 dagars ålder. De deskriptiva analyserna visade att suggorna som avvandes från smågrisarna vid 35 dagars ålder hade mindre ryggfett än suggorna i de andra grupperna. Ju längre suggorna stannade med smågrisarna, desto mindre hade de kontakt med smågrisarna med trynet, och andelen av tid som de stod upp ökade med tiden. Resultaten som gäller suggorna bekräftades dock inte i de statistiska analyserna. Eftersom den här uppsatsen är en pilotstudie med ett litet antal djur så bör resultaten tolkas med försiktighet. Däremot visar resultaten på ett behov av fortsatta studier för att bekräfta om de här resultaten är applicerbara på större populationer.

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Abbreviations

BW	Bodyweight
DY	Dutch Yorkshire
FPS	Frames per second
H	Hampshire
SLU	Swedish University of Agricultural Sciences
SE	Standard error
SPF	Specific Pathogen Free
Std dev	Standard deviation
SY	Swedish Yorkshire

1. Introduction

The wild boar was domesticated about 10,000 years ago. Humans have selected for different traits during the last 200 years, resulting in the commercial breeds of the domestic pig (*Sus scrofa domesticus*) (Rothschild & Ruvinsky 2011). Those breeds are the ones used in commercial farms today (Rothschild & Ruvinsky 2011). Although the aims of pig production are many, the pig producers' primary aims are to produce qualitative meat that is cost-efficient and produced in a way accepted by the general public (Webb 1998). In practice, this has resulted in increased litter sizes and decreased age of weaning, resulting in increased numbers of pigs per sow and year, ultimately leading to improved efficiency and economic gain (Webb 1998; Rutherford *et al.* 2013). There are also numerous other effects such as increased growth- and feed conversion rates on piglets and improvements of housing, health management and feed quality for piglets and sows (Prunier *et al.* 2010). However, it has been suggested that the modifications of production rates put demands on the pigs at a level that cannot be physiologically met (Prunier *et al.* 2010). Several modifications in the environment and genetics have been made to compensate for these demands. Still, there are restrictions as to what modifications are possible due to, for example, the size of the animals or the costs of the necessary modifications (Prunier *et al.* 2010).

The European legislation states that the weaning age in pigs can be a minimum of 21 days if specific criteria are met and 28 days without these criteria (Council of the European Union 2008). Further, Swedish legislation states that up to 10 % of piglets can be weaned at 21 days of age if additional Swedish legislation criteria are met (SJVFS 2019:20 Saknr L106 3 Kap. 2 §).

The effects of different weaning ages on piglets have been studied several times before, with its primary focus on aspects such as effects on gut development and growth, while some have focused on behavioural aspects (Orgeur *et al.* 2001; Grümpel *et al.* 2018; Huting *et al.* 2019). The few studies made on the effects on the sow have been inconclusive, with no significant difference in body weight (Van Der Meulen *et al.* 2010; Wallgren & Gunnarsson, 2015). Due to the lack of knowledge previously mentioned, and even more so in Swedish conditions, this thesis aims to map and understand how different weaning age affects sow and piglet behaviour on a conventional Swedish farm.

The aim of this project is, more specifically, to provide an answer to the following questions:

1. What are the effects of weaning age on weight, body condition, and behaviour in sows housed in an environment similar to Swedish commercial piglet production?
2. What are the effects of weaning age on weight gain and behaviour in piglets housed in an environment similar to Swedish commercial piglet production?
3. Are there possible conflicts between the needs of the sow and the piglets that link to the weaning age?

2. Literature review

2.1. European and Swedish legislation

The pig population in the European Union (EU28) contained approximately 41 million piglets of less than 20 kg in 2019 (Eurostat, 2019). It has been recommended that piglets in the European Union should not be weaned before four weeks of age (EFSA, 2007). Neither should they be weaned before a significant creep feed-intake has been developed (EFSA, 2007). The arguments for these recommendations are that earlier weaning affects weight gain and gastrointestinal processes negatively and affects behaviour, resulting in belly nosing, frustration, and injuries caused by chewing at the other piglets in the group.

The European Union have regulations considering minimum standards and welfare in pigs for production (Council of the European Union, 2008/120/E.C.). These regulations consider, amongst others, the minimum amounts of nesting material for sows and the necessity to protect the piglets from injuries using farrowing rails in loose house systems and standardised weaning procedures. It states that piglets are allowed to be weaned from 28 days of age (Council of the European Union, 2008). However, the same legislation also notes that a weaning age of up to seven days earlier may be allowed if the following requirements are fulfilled; piglets must be moved to a separate building from the sows. The building must be cleaned disinfected between groups of piglets.

Sows and gilts can be kept in farrowing crates or pens. Some countries have further regulations complementing the EU Council Directive (2008/120/E.C.) regarding group housing in sows and gilts (Mul *et al.* 2010). Sweden is one of them. SJVFS 2019:20 (Saknr L106 3 Kap. 10 §) states that sows can be kept in farrowing pens. Movement should only be compromised with a protective gate if she shows aggressive or abnormal behaviour that may result in injuries on the piglets. The caretakers can constrain the sow with a protective gate during specific procedures if the sow or gilt shows aggressive behaviour towards the animal caretakers. Sows and gilts may be kept in individual farrowing pens a week before farrowing and during the suckling period (SJVFS 2019:20 Saknr L106 3 Kap. 8 §).

Swedish law states that piglets can be weaned from 28 days of age. However, 10 % of the piglets in a herd can be weaned up to seven days earlier if several criteria listed in the legislation are fulfilled (SJVFS 2019:20 Saknr L106 3 Kap. 2 §). The requirements are as follows:

- The herd is connected to a voluntary organised health programme.
- The herd is connected to the voluntary biohazard programme for pig herds "Smittsäkrad besättning gris" (currently only available in Swedish).
- The piglets are bred in batches which are kept separately and are moved to another section after weaning.
- Those sections are empty for five days between batches and are cleaned and disinfected before another batch moves in.
- Litter levelling is not performed when the piglets are more than 48 hours old.
- The piglets are, in enough amounts, fed an optimised feed that is milk-based after weaning.
- A maximum of 10 % of piglets in a batch may be weaned before 26 days of age.
- The piglets have a normal weight for their age.
- After weaning, no behavioural disorders such as Belly nosing and tail-biting occurs more than occasionally.
- The sections used after weaning has a facility for additional heating.
- A reserve power plant is located on the facility.

2.2. Pig behaviour

Despite domestication and current rearing conditions, the domesticated pig's behaviour and physiology remain similar to their wild ancestors, which has been the subject of several studies where pigs have returned to their natural conditions (Jensen 1986; Jensen & Recén 1989; Gustafsson *et al.* 1999). When comparing maternal behaviour between the domestic pig and crosses with wild boar, the sows showed very similar behaviour patterns between groups (Gustafsson *et al.* 1999). The domestic sows would let the piglets massage the udder for a more extended period after milk ejection than the wild boar cross during the first two weeks after farrowing. In contrast, the wild boar sows would terminate the nursing at a greater proportion than the domestic sow. The study showed that the domestic sows had a greater tendency to lie down during the third week, while the wild boar crosses would have more nose contacts with the piglets than the domestic sow. The changes in behaviour, although relatively small, can be a consequence of human altering of the pigs' environment and the human protection of the pigs (Gustafsson *et al.* 1999).

In the Swedish system, where sows are loose housed, the piglets' mortality depends on the sow's maternal characteristics (Andersen *et al.* 2007).

The emotional state of pigs can be indicated through behavioural responses to different events (Reimert *et al.* 2013). Play behaviour, barking and tail movement can be indicators of positive emotions, while negative emotions can be indicated by escape attempts, screams and squeals, freezing, urination and defecation and body movements such as lowered tail or ear movement (Reimert *et al.* 2013, 2017). Aggressive behaviours displayed as fights increase when piglets are exposed to social alterations, while also lying down less (Colson *et al.* 2012). One pig's emotional state has been suggested to transmit to other pigs through emotional contagion (Reimert *et al.* 2013). Emotional contagion is described as a simple form of empathy in which one pig's emotional state affects the emotional state of other pigs in the same pen (Reimert *et al.* 2013).

2.2.1. Abnormal behaviour

Normal behaviour can be described as behaviours developed through evolutionary adaptations, while abnormal behaviours can be described as behaviours that deviate from the behaviours that occur in natural conditions (Keeling & Jensen 2009). However, behaviours are not consistent, and deviations typically occur due to individual differences and experiences (Keeling & Jensen 2009). Another important aspect is that abnormal behaviour can be expected among a species due to the environment in which they are kept. Keeling & Jensen (2009) exemplify this with the occurrence of abnormal behaviour in caged egg-laying hens. Many of the world's total hens are kept in cages and show abnormal behaviour related to the cage. One may, therefore, not conclude that a frequently displayed behaviour is normal only due to its occurrence among many individuals of a species.

2.3. Definition of weaning

Weaning in natural conditions is usually defined as when the young stops suckling and exclusively eats solid feed (Counsilman & Lim 1985). In pig production, weaning can be defined as removing the sow from the piglets or removing the mother's milk or as a combination of both (Schmitt *et al.* 2019). The removal of the mother from its young earlier than what is naturally occurring can be described as maternal deprivation and take place in all commercially reared animals because of the vital profit of fast reproductive cycles (Latham & Mason 2008). The mean weaning age of piglets in Sweden was 32.3 days in 2020 (Gård & Djurhälsan, 2021b).

2.3.1. Natural weaning

In natural conditions, the weaning age has not been defined as a specific point in time but rather a prolonged process of gradually becoming used to other feeds than the sows' milk (Gill & Thomson 1956; Jensen 1986; Jensen & Recén 1989; Worobec *et al.* 1999). One suggestion has been that natural weaning occurs between 14 and 17 weeks of age, with, amongst others, seasons having effects on the weaning age (Jensen 1986; Jensen & Recén 1989). The weaning age is also gradual within a litter; all piglets are not weaned at the same time, and by six weeks of age, half of the dry-matter intake by most of the piglets will no longer be received by the sows' milk (Muirhead 1990; Worobec *et al.* 1999). The weaning age is also dependant on litter size, where small litters are weaned later (Bøe 1991). The sow will usually be the one to terminate the nursing sessions from four weeks of age and thereby control the milk received by the piglets over time since the time spent massaging the teats are correlated with milk yield (Gill & Thomson 1956; Jensen & Recén 1989). Under natural conditions, the distances between the piglets and sow gradually increase with age, with 20 meters at two weeks, increasing to 40 meters at four weeks of age (Jensen 1986). When the sow could choose the time spent with the piglets in another study, the sow would spend 13 out of 24 hours with its young (Bøe 1991). The hours spent with the piglets would gradually decrease, and at ten weeks of age, the sow spent approximately two hours with the piglets in 24 hours.

Piglets react differently to weaning between as well as within litters (Mason *et al.* 2003). For example, piglets that suckled the anterior tits were the heaviest ones in the litters, both pre-and post-weaning (Mason *et al.* 2003). They were less prone to make high vocalisations and more prone to make low vocalisations. Furthermore, they had higher salivary cortisol levels after weaning. The same study suggested that the larger piglets experienced more nutritional deprivation after weaning, while the smaller piglets experienced more stress derived from maternal deprivation.

A study on the behaviour of social isolation from the litter in a newly weaned group of piglets showed that social isolation triggered behaviours such as scraping the hoof and escape attempts while simultaneously reducing the occurrence of play behaviour (Herskin & Jensen 2000).

2.3.2. Effects of different weaning ages on piglets

Several studies state behavioural and physiological issues regarding the effects of early weaning on piglets (Weary *et al.* 1999; Worobec *et al.* 1999; Orgeur *et al.* 2001; Latham & Mason 2008; Van Der Meulen *et al.* 2010). It has been shown that early-life events can affect behavioural responses to stressors later in life (Anisman *et al.* 1998). Furthermore, social isolation has been proven to cause stress responses (Anisman *et al.* 1998). Belly nosing is a behaviour that increases with earlier weaning and is also correlated with stressful conditions after weaning (Algers 1984).

Piglets weaned as early as one week of age showed increased, yet, partly transient vocalisation, movement, aggression, and belly nosing compared with a group of piglets that stayed with the sow for the entire duration of the experiment (Orgeur *et al.* 2001). The piglets vocalised and moved more than usual during the first two days after weaning. Most aggressive behaviours disappeared after two weeks from weaning, while belly nosing persisted during the experiment's entire duration at day 20. The piglets weaned at one week of age showed earlier maturation of their gut immune system.

Piglets weaned at two weeks of age, vocalised, and belly nosed more than piglets weaned at four weeks of age (Weary *et al.* 1999). This specific study also showed that the diet of the early-weaned piglets did not affect these consequences. Another study found that piglets weaned at 12 days of age would nose and chew on other pigs during the entire duration from weaning to the finishing period compared with piglets weaned at 21 days of age (Gonyou *et al.* 1998). In the same study, it was found that piglets weaned at 21 days of age spent more time eating during the first 48 hours after weaning, while the piglets weaned on day 12 would eat and drink more than the piglets weaned later on. A comparison between the weaning ages of 21 and 35 days showed that the piglets weaned on day 35 had lower salivary cortisol levels and vocalised less than the early-weaned piglets (Mason *et al.* 2003). Tail lesion prevalence is higher when the weaning age is <25.3 days (Grümpel *et al.* 2018). Weaning four-week-old piglets resulted in an increased stress response, less growth and feed intake than piglets weaned at seven weeks of age (Van Der Meulen *et al.* 2010). Stress was measured with plasma cortisol.

A recent study showed that the benefits of later weaning age were evident in lightweight and heavyweight piglets (Huting *et al.* 2019). The benefits were especially clear in lightweight piglets, who reached 60 kg bodyweight four days earlier if they were weaned later, where a weaning age of 21 days was compared with a weaning age of 28 days. In order to accustom the piglets to solid food, piglets can be provided with small amounts of solid food before weaning. This slow increase of solid food in the piglets' diet is called creep feed (Weary *et al.* 2008).

2.3.3. Effects of different weaning ages on sows

In a Swedish study containing 24 herds, the number of piglets in each litter from Swedish gilts had increased from 10.8 to 13.0 between the years 1997 to 2009 (Andersson *et al.* 2016). The numbers were slightly higher in the second parity, with 11.2 piglets in 1997 and 13.9 in 2009. Berg (*et al.* 2020) mentions this in their report and provides statistics from Swedish herds concluding that an estimated increase of two piglets per sow has been weaned between 2000 and 2016. The mean numbers of piglets in litters had reached 15.0 liveborn piglets in 2020 (Gård och djurhälsan, 2021a). The national increase of weaned piglets reflects the Pig Research Centre of the Swedish University of Agricultural Sciences (Berg *et al.* 2020). There is, however, no evidence of any increase in the individual weight of the piglets before weaning (Berg *et al.* 2020). The number of piglets per year for each sow is negatively associated with increased weaning age and sow stayability (Andersson *et al.* 2016; Chantziaras *et al.* 2018).

The welfare of sows depending on weaning age is a topic that has not been thoroughly researched. The effects of shorter weaning age on sow and piglet health and welfare in Swedish conditions was investigated in a pilot study organised by Sveriges Grisföretagare, the Swedish pig breeder organisation, in 2014. After that, the study results were analysed in a report by Wallgren & Gunnarsson (2015). This report found no increase in body fat of the sows with decreased weaning age. However, it was found that the reduced weaning age resulted in a rise in piglets for each sow and year. Van Der Meulen (et al. 2010) found no significant difference in the weaning-to-oestrus interval or bodyweight of the sow depending on whether the piglets were weaned at 4 or 7 weeks of age. Wallgren & Gunnarsson (2015) state that it is crucial to balance sow health and welfare benefits against the piglets' adverse effects, such as the risk of infection and stereotypical behaviours. The Scientific Council recently brought the subject up for Animal Welfare at the Swedish University of Agricultural Sciences (Berg *et al.* 2020). This report stated similar conclusions as to the previous report but with a slightly different perspective. The report concluded that the piglets were negatively affected by a decreased weaning age in a physiological sense due to the immune system's development and digestive tract in the fourth week after birth. Regarding the effects on the sow, they concluded that research on sow weight, health and behaviour is missing in this specific field of study. Any research on these factors in other settings, such as increased weaning age or different housing systems, were not considered applicable.

With the background of these reports and conclusions, it is evident that sows' welfare depending on their piglets' weaning age has not been as thoroughly researched as its effects on the piglets. It is also clear that there is a lack of knowledge on how different weaning ages affect piglets in Swedish housing systems.

3. Methods

Ethical approval for animal experiments was received from Uppsala's Swedish ethical review authority (ref.no. 5.8.18-13161/2020). The data was collected between the 2^{nd} of December 2020 and the 15^{th} of March 2021. The collection of data was conducted at the Pig Research Centre of the Swedish University of Agricultural Sciences at Funbo Lövsta, Uppsala.

3.1. Animals

This study included 19 sows of Swedish and Dutch Yorkshire breeds divided into three groups. They were grouped depending on the weaning age of the piglets (table 1). Sows were selected into groups depending on when they farrowed to easily integrate them with the rest of the sow herd after the study was finished.

Table 1. Age of piglets during weaning and the number of sows in each group of sows in the study. The results of weaning were shown the following week. The numbers in the parentheses state the number of sows in each treatment that was not filmed.

	Treatment 3	Treatment 4	Treatment 5	
Weaning (weeks of age)	3	4	5	
Weaning (days of age)	23, 23, 22, 21, 21	29, 29, 29, 28, 28	35, 36, 35, 35, 39, 35	
Number of sows	5(+2)	5(+1)	6	Total 16(+3)

In this study, 16 sows were continuously recorded one week before expected farrowing until weaning. All sows were divided into three subgroups depending on when the piglets were weaned. The piglets were weaned on or close to day 21, 28 and 35 (see table 1). The piglets stayed in the farrowing boxes up until nine weeks of age. The sows were returned to the dry sow unit after weaning. Before farrowing and after weaning, the sows were weighed, and back-fat thickness was measured according to management routines (Centre 2017). Weaning was defined as removing the sow from the piglets.

Table 2. Routines for each group of piglets for the duration of the study. Treatment 3 is weaned on day 21, treatment 4 is weaned on day 28 and treatment 5 is weaned on day 35. Some litters were weaned a couple of days before or after the planned day of weaning.

Treatment	3	4	5
0 days	Weighed, gender determination, earmarking	Weighed, gender determination, earmarking	Weighed, gender determination, earmarking
Five days	Iron injection, ear tag	Iron injection, ear tag	Iron injection, ear tag
Seven days	Feed introduction	Feed introduction	Feed introduction
14 days	2^{nd} iron injection	2^{nd} iron injection	2^{nd} iron injection
21 days	Weighed, *weaned*	Weighed	Weighed
28 days	Weighed	Weighed, *weaned*	Weighed
35 days	Weighed	Weighed	Weighed, *weaned*
Nine weeks	Weighed	Weighed	Weighed

3.2. Housing and management

The research centre in which the study was conducted is a Specific Pathogen Free (SPF) herd, meaning that animals from other herds are not recruited, and the existing animals are regularly tested for common infectious pig diseases (Centre 2017). The sows were kept in individual pens approximately seven days before expected farrowing (figure 1). They stayed there until the piglets were weaned, which varied depending on which test group the sow belonged to. The sows were fed dry feed three times per day during the entire study period, at 06.30, 12.30 and 18.00. Each farrowing unit contained 12 farrowing pens used in shifts, where 6 to 12 sows are farrowing every two weeks. The piglets were introduced to small amounts of piglet feed on day 7. The feed was scattered on the floor up until 14 days of age. After that, an automated pig feeder was installed and used.

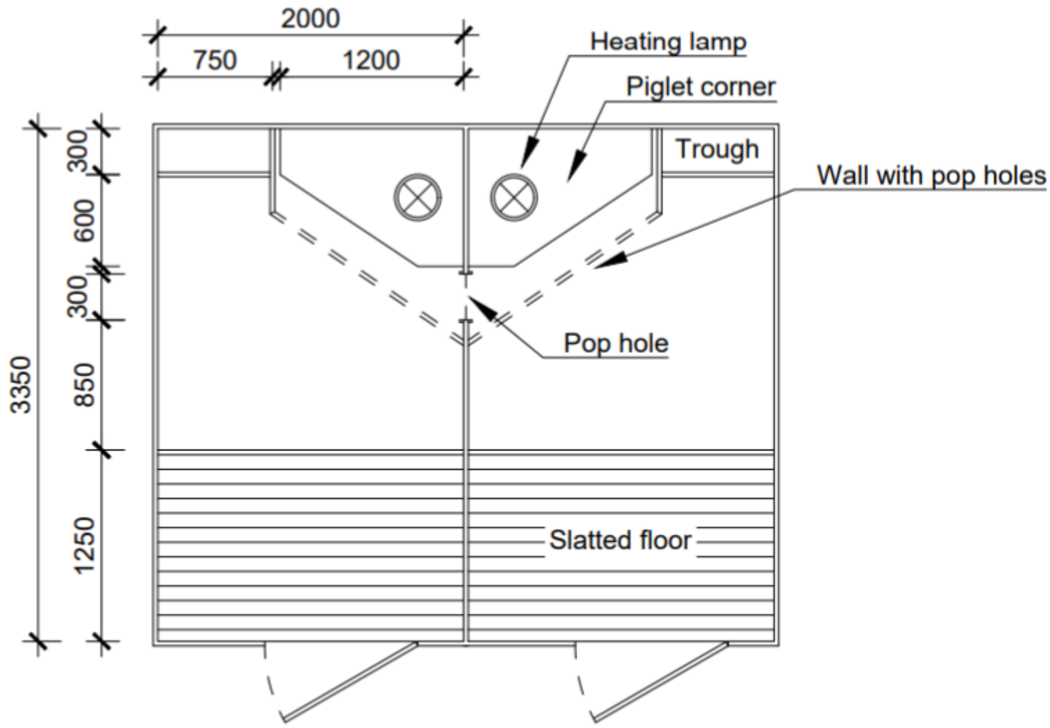


Figure 1 An illustration of the loose housed farrowing pens in the pig facility used in this study. The pop holes between pens were closed during this study. Illustrated by Andersson (2019).

3.3. Study design

3.3.1. Behavioural observations of sows and piglets

Cameras were placed above each pen for the entire observation period. The cameras used in this project were Dahua Vandal Proof Wi-Fi Dome Cameras with 1 FPS.

Behavioural registration was executed in Excel while using VLC Media Player for the observations. Since no observers were on site and the cameras were installed before farrowing, there was no need for an acclimatisation period before the observations. Any observations that occurred on the same day as the weaning day were considered to be occurring after weaning.

3.3.2. Continuous registration of sow and piglet behaviours

The continuous recordings were conducted between day 14 and 44 from farrowing. Each week, observations were made on day 1 and 3 (i.e day 14, 16, 21, 23, 28, 30 etc). The behaviours of weaned piglets are shown from the week after their weaning age in all graphs in the results; treatment 3 in week 4, treatment 4 in week 5, treatment 5 in week 6. During the continuous registrations, all animals in the farrowing pen were observed simultaneously according to the ethogram (table 3). Each observation lasted 5 minutes and was divided into one-minute intervals. During the observations, the number of occurrences of each behaviour was registered. Observations were conducted three times each observation day; 09:00, 13:00, and 17:00. The interval was skipped if staff entered the farrowing pen or if animals were removed from the pen to undergo treatment, according to table 2.

Table 3. Ethogram for interaction analysis using continuous recording.

Behaviour category	Behaviour definition	Description	Registration
Sow			Continuous recording
Body position	Standing still	All hooves on ground	Repetitions/min
	Moving	Moving between areas of the pen while standing upright	Repetitions/min
	Lying down on stomach	Stomach is in contact with the floor, back is toward the ceiling	Repetitions/min
	Lying down on side	One side of the stomach is in contact with the floor	Repetitions/min
	Sitting	Front hooves and rear is in contact with the floor	Repetitions/min
Activity	Eating	Head positioned in the feed truff	Yes/No
	Drinking	Snout is in contact with the water nipple	Yes/No
	Nosing piglet	Snout is facing towards and close to/in contact with a piglet	Repetitions/min
Piglets			Continuous recording
	Social play behaviour	Jump up and down, rotate while jumping, bouncy movements, tossing head	Repetitions/min
	Fights	head-to-body knocks, head-to-head knocks, pressing of shoulders against each other	Repetitions/min
	Mounting	Standing with front legs on the back of another piglet	Repetitions/min
	Belly nosing	Making suckling movements with the snout on the stomach of another piglet	Repetitions/min
Suckling		More than 50 % of piglets are making suckling movements while the sow is laying on the side	Yes/No

3.3.3. Scan sampling of sow and piglet behaviour

Scan samplings were conducted on the same days as continuous registrations (table 4). The behaviours of weaned piglets are shown from the week after their weaning age in all graphs in the results; treatment 3 in week 4, treatment 4 in week 5, treatment 5 in week 6. In each scan sample, all animals' body position and activity in the farrowing pen were registered using still pictures from the recordings. Scans were made once every hour between 07:00 and 20:00. All scans where staff entered the pen or animals were removed to undergo any treatment, according to table 2, were not included in the data.

Table 4. Ethogram for time budget analysis using scan sampling.

Behaviour category	Behaviour definition	Description	Registration
Sow			Scan sampling
Body position	Standing	All hooves on the ground, spine is level with the ground	0/1
	Sitting	Front hooves on the floor, rear on the floor, spine is horizontal.	0/1
	Lying stomach	Lying down with hind legs under the body	0/1
	Lying on side	Lying down with both hind legs on the side	0/1
Location in pen	Slatted floor	Majority of the body is on the slatted floor	0/1
	Concrete floor	Majority of the body is on the concrete floor	0/1
Activity	Eating	Head is in the sow feed truff	0/1
	Drinking	Snout in contact with the water nipple	0/1
	Manipulating furniture	Snout is close to or in contact with the walls or metal bars	0/1
	Manipulating floor /straw	Snout is facing toward the floor	0/1
	Straw in mouth	Straw in mouth, snout is not toward the floor	0/1
	No activity	Standing still, snout in the air	0/1
	Interaction with piglet	Snout is facing towards and close to/in contact with a piglet	0/1
	Interaction with sow in another pen	Snout is reaching towards another pen while in contact with the wall while another sow is mirroring the behaviour on the same spot	0/1
Piglets			Scan sampling
Body position	Standing	All hooves on the ground	Number of piglets, 0/1
	Sitting	Front hooves on the floor, Rear on the floor	Number of piglets, 0/1
	Lying	Stomach or side of the body is in contact with the floor or another lying piglet	Number of piglets, 0/1
Location in pen	Piglet corner	Majority of the body is in the piglet corner. Piglet corner is defined as the roofed part of the pen and the rest of the delimited corner	Number of piglets, 0/1
	Piglet corner after weaning	Majority of the body is in the piglet corner or in contact with another piglet in the corner if it is crowded. The piglet corner is defined as the roofed part of the pen	Number of piglets, 0/1
	Slatted floor	Majority of the body is on the slatted floor	Number of piglets, 0/1
	Concrete floor	Majority of the body is on the concrete floor	Number of piglets, 0/1
Activity	Eating	Snout is placed in the automatic feeder	Number of piglets, 0/1
	Sow feed	Snout is placed in the sow feed truff	
	Drinking	snout is in contact with or reaching toward the water nipple	Number of piglets, 0/1

3.3.4. Physiological parameters of sows and piglets

All piglets were weighed according to table 2. Sows were weighed, and backfat thickness was measured using ultrasound when the piglets were weighed after farrowing and in conjunction with weaning.

3.4. Statistical analysis

The statistical analysis and display of this study's results were conducted in the SAS version 9.4 Software (SAS Institute, Inc. 2011). The UNIVARIATE procedure was performed to test for normal distribution. Variables that differed significantly from normal distribution were converted to bivariate variables. The normally distributed variables were analysed with the GLM procedure, which is suitable for input variables that are non-random and for output variables with normal distributions. All non-normally distributed variables were analysed with the GLIMMIX procedure, which is suitable for non-normally distributed outputs.

3.4.1. Continuous registration of sow and piglet behaviour

3.4.1.1 Data editing and changes of sow and piglet behaviour variables

Before the analysis, data from the sow behaviours *lying stomach* and *lying side* were converted into a single new variable, *lying*, which included both registered body positions.

3.4.1.2 Descriptive statistics of sow and piglet behaviour variables

Continuous registration was used to measure the sow and piglet behaviours and interactions. The FREQ procedure in SAS was used to create frequency tables of the behaviours and differences between weeks of lactation. For piglet behaviours, differences in frequencies between treatment were also calculated. As the variables were not normally distributed, they were converted to binary variables before further analysis, meaning that the variables were counted as occurring or not occurring in each observation. After that, the MEANS procedure was used to show the proportions of observations in which the behaviours occurred.

3.4.1.3 Statistical analysis and modelling of sow and piglet behaviour variables

Drinking (table 3) were excluded from the analysis due to low observation numbers. *Standing* and *sitting* was not included in the statistical analysis as *standing* and *sitting* are reflecting each other. *Lying* was used as a marker for inactivity.

The data was processed in SAS to analyse the effects of treatments and weeks statistically. The behaviours were analysed with two different generalised linear models depending on whether they depended on the sow being in the pen or not.

Sow behaviours and nursing were dependent on sow presence and was therefore included in the first model. The least-square means were estimated for each week and compared between weeks within each treatment. The first model was created to analyse the percentage of recordings in which the variables occurred. The model analysed with the GLIMMIX procedure was:

$$y = week + time + sow + e$$

Week had three classes (week 2-4), and time had three classes (9:00, 13:00, 17:00). The sow was included as a random effect, while the other variables were included as fixed effects. In the model, y was the response variables, and e represented the residual error.

Differences in piglet behaviours between treatments were analysed using the GLIMMIX procedure for each week of lactation separately using the following model:

$$y = treatment + time + piglet + e$$

Where treatment had 3 classes (treatment 3-5) and time had 3 classes (9:00, 13:00, 17:00). The piglets were included as a random effect, while the other variables were considered as fixed effects. In the model, y was the response variables, and e represented the residual error.

3.4.2. Scan sampling of sow and piglet behaviour

3.4.2.1 Data editing and changes of sow and piglet behaviour variables

Before the analysis, data from the sow behaviours *lying stomach* and *lying side* were converted into a single new variable, *lying*, which included both registered body positions.

3.4.2.2 Descriptive statistics of sow and piglet behaviour variables

Scan sampling was used to calculate the time budget of sows and piglets. The FREQ procedure was used to create frequency tables of the sow and piglet behaviours and locations in the pen. Frequencies for the different piglet behaviours and piglet location in pen were calculated for the different treatments.

3.4.2.3 Statistical analysis of sow and piglet behaviour variables

Some behaviours included in the ethogram (table 4) were excluded from the analysis due to low observation numbers. *Drinking* was excluded for piglets and sows, and *manipulating furniture*, *manipulating floor/straw*, *straw in mouth*, *interaction with sow in another pen* and *interaction with piglet* were all excluded regarding sow behaviours. *Standing* was not included in the statistical analysis as *standing* and *sitting* are reflecting each other. *Lying* was used as a marker for inactivity.

The behaviours were analysed with two different general linear models depending on whether they were sow- or piglet variables. Differences in sow behaviour and location in pen between weeks were analysed separately for each treatment using the GLM procedure with the following model:

$$y = week + litter\ size + e$$

Where weeks had three classes (weeks 2-4), weeks was included as a fixed effect and litter size was included as a continuous covariate. In the model, y was the response variables, and e represented the residual error.

Differences in piglet behaviour and position in pen were analysed separately for each week using the GLM procedure with the following model:

$$y = treatment + litter\ size + e$$

Treatment had three classes (treatment 3-5) and was included as a fixed effect, while litter size was included as a continuous covariate. In the model, y was the response variables, and e represented the residual error.

3.4.3. Physiological parameters of sows and piglets

3.4.3.1 Data editing and changes of variables of physiological parameters of sows and piglets

Differences in weights between different ages were calculated and formed new growth variables.

3.4.3.2 Descriptive statistics of physiological parameters of sows and piglets

The MEAN procedure was used to calculate means and standard deviations for weight change, backfat thickness change and growth variables.

3.4.3.3 Statistical analysis of physiological parameters of sows and piglets

Differences in weight change, backfat thickness change and growth between treatments were analysed using the GLM procedure with the following model:

$$y = treatment + litter\ size + initial\ value\ of\ period + \ e$$

Treatment had three classes (treatment 3-5) and was included as a fixed effect. Litter size was included as a continuous covariate. The initial value of period was the weight or backfat thickness at the start of the change in weight, backfat thickness or growth, and was included as a continuous covariate. In the model, y was the response variables, and e represented the residual error.

4. Results

4.1. Continuous recording of sow and piglet behaviour

4.1.1. Descriptive statistics of sow and piglet behaviour

Means and standard deviations (std dev) were estimated for all behaviours to display the frequency of behaviours throughout the recordings.

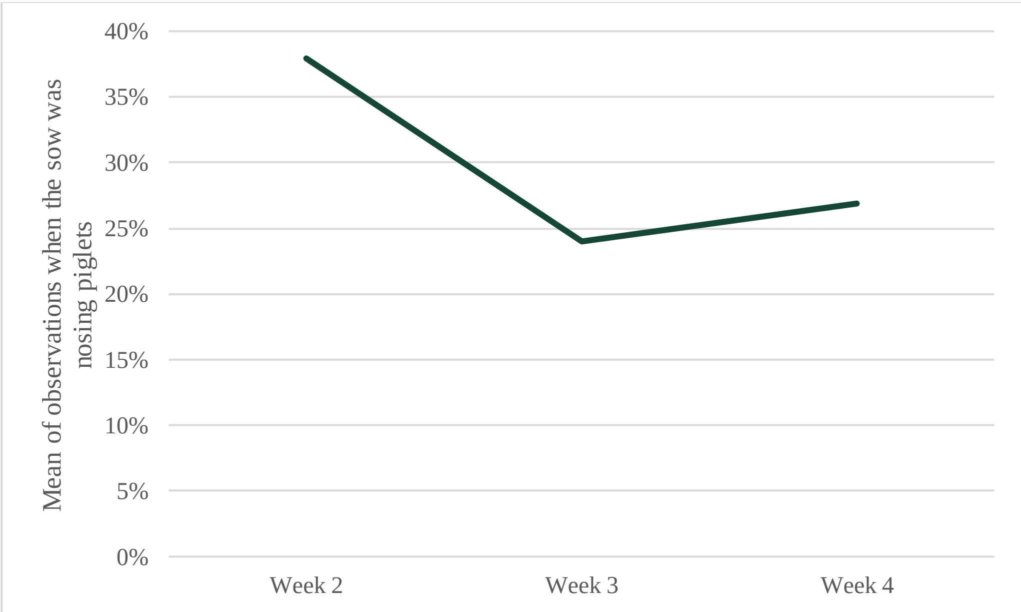
On average, *nursing* was performed during 16 % (std dev 36.74 %) of the 890 observation minutes divided over 16 sows (table 5). There were no significant effects of weeks. *Moving* (8.09 %, N=890), *eating* (9.89 %, N=890), and *drinking* (3.26 %, N=890) were not included in the statistical analysis due to the low number of subjects in the project, occurrences during the observation periods and lack of effects between weeks (table 5). *Nosing* had a mean prevalence of 28.99 % (std dev 45.4 %) and was included in the statistical analysis (table 5). All piglet behaviours listed above were also included in the statistical analysis (table 5).

Table 5. Mean proportion of observation minutes, where sow behaviours or nursing occurred at least once. N= Number of observation minutes, divided over 16 sows.

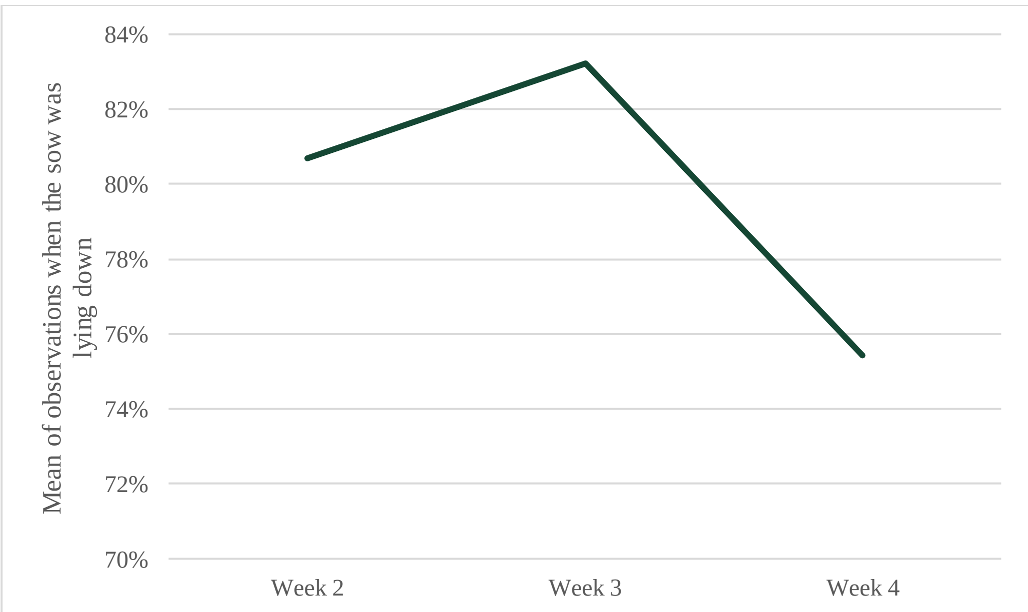
Variable	N	Mean (%)	Std Dev (%)
Nursing	890	16.1	76.7
Nosing piglet	890	29.0	45.4
Lying	889	78.1	41.4
Moving	890	8.1	27.3
Eating	890	9.9	29.9
Drinking	890	3.3	17.8

Table 6. Proportion of observation minutes, divided over 16 litters, where piglet behaviours occurred at least once. Mean and standard deviation (std dev) of binary occurrence in observations. 16 litters included in the analysis. N= observation minutes per litter

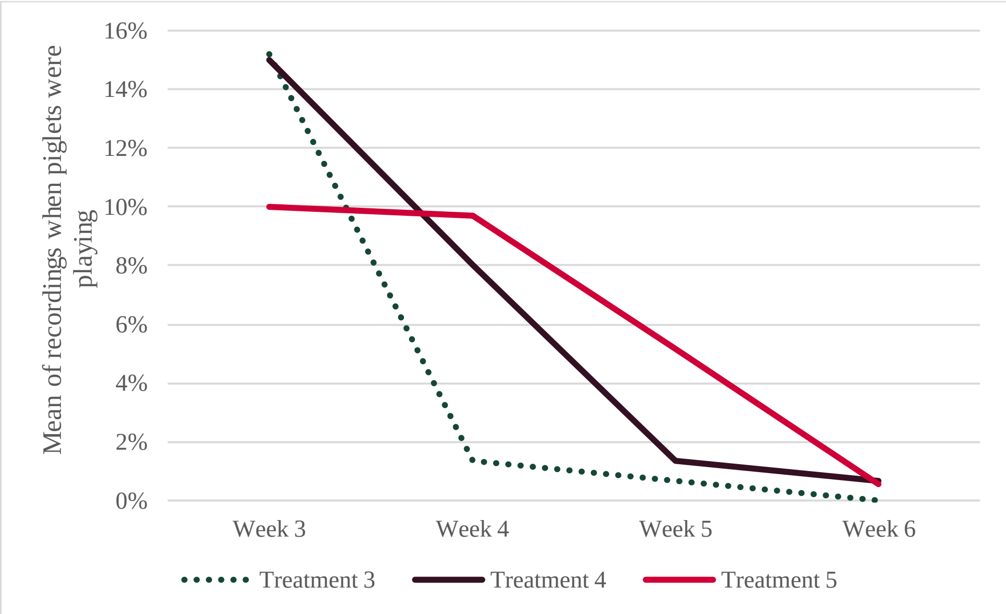
Variable	N	Mean (%)	Std Dev (%)
Play	2223	7.6	26.5
Fights	2223	8.9	28.5
Mounting	2223	5.4	22.5
Belly nosing	2223	7.6	26.5



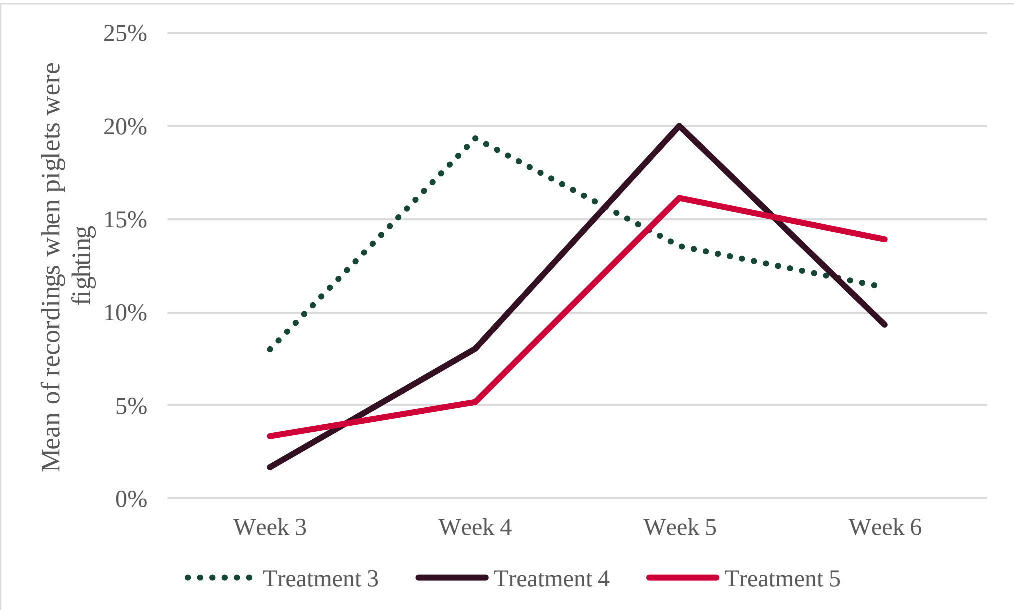
Graph 1. Timeline of the mean occurrence of sow nosing behaviour for treatment 5 between weeks 2-4. Six sows in treatment 5 were included in the analysis. N=890 sow observation minutes



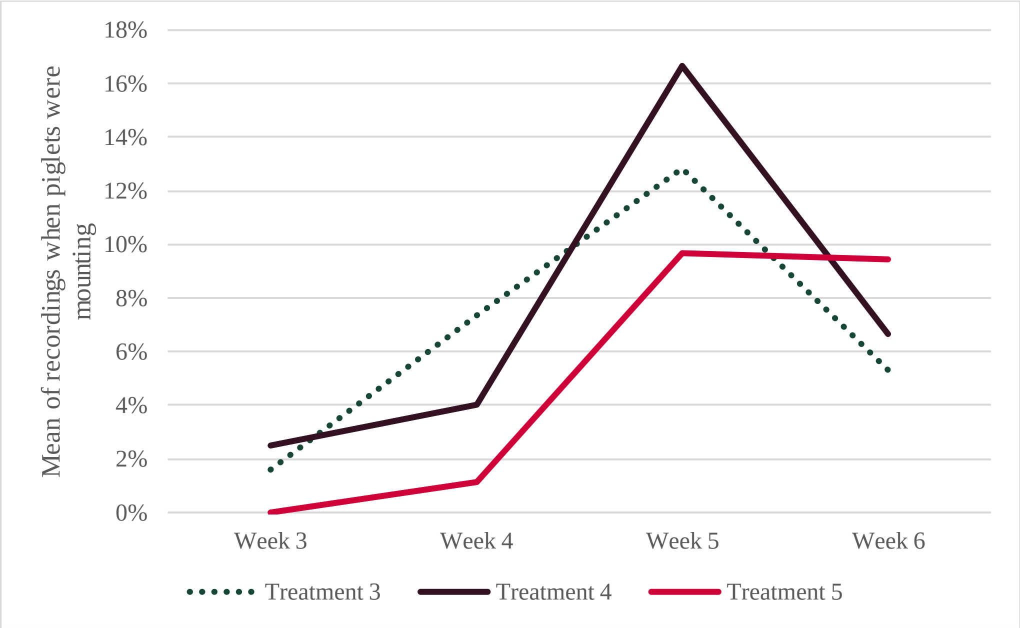
Graph 2. Timeline of the mean occurrence of sow lying behaviour for treatment 5 between weeks 2-4. Six sows in treatment 5 were included in the analysis. N=890 sow observation minutes



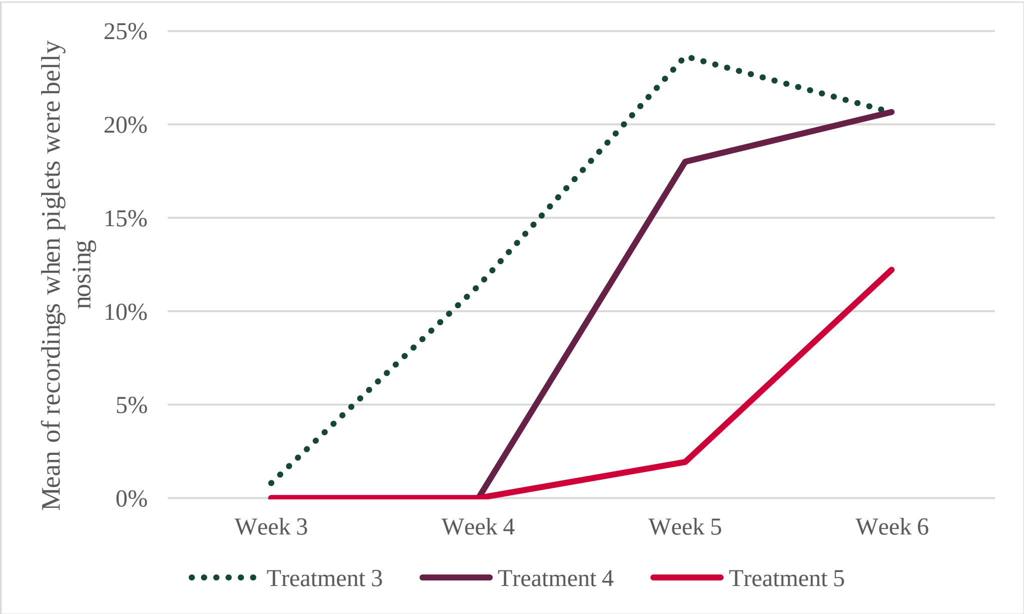
Graph 3. Timeline of the mean occurrence of piglet play behaviour in piglets for each treatment during weeks 3 – 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 2223 litter observation minutes



Graph 4. Timeline of the mean occurrence of piglet fight behaviour for each treatment during weeks 3 – 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 2223 litter observation minutes



Graph 5. Timeline of the mean occurrence of piglet mounting behaviour for each treatment during weeks 3 – 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 2223 litter observation minutes

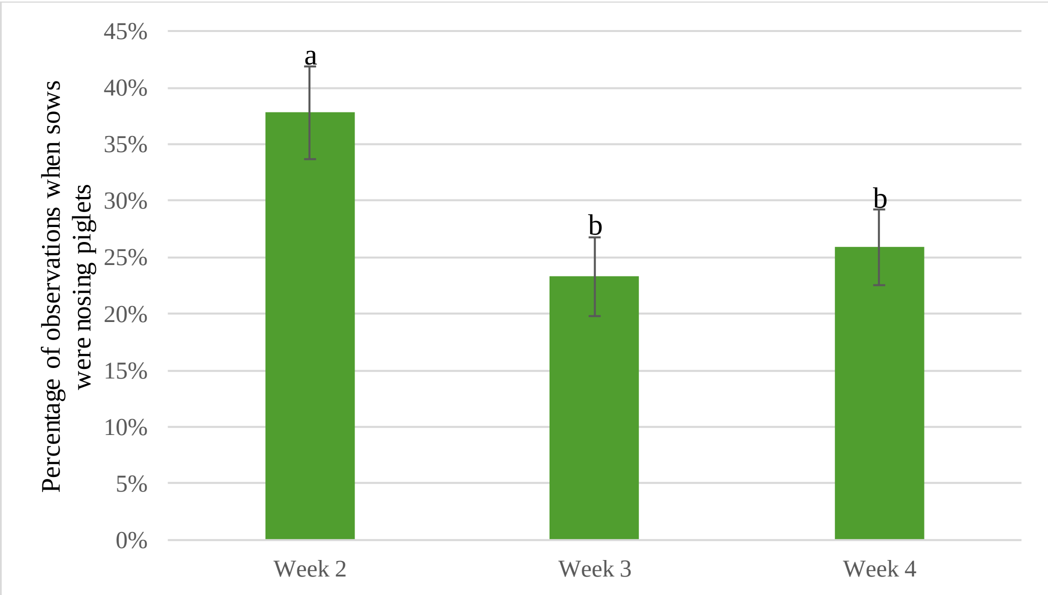


Graph 6. Timeline of the mean occurrence of piglet belly nosing behaviour for each treatment during weeks 3 – 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 2223 litter observation minutes

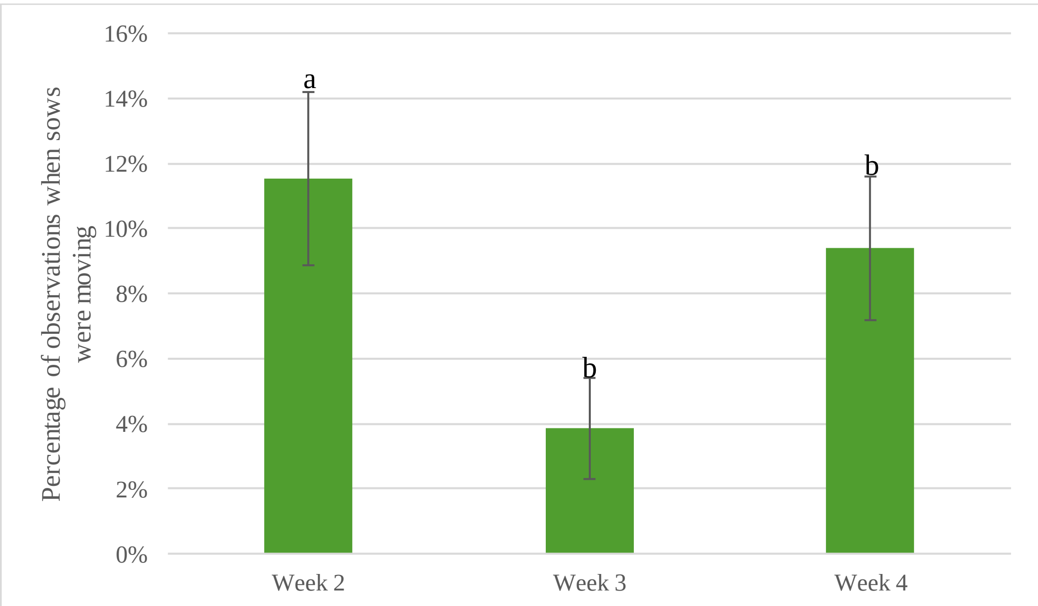
4.1.2. Statistical analysis of sow and piglet behaviour

4.1.2.1 Sow behaviour

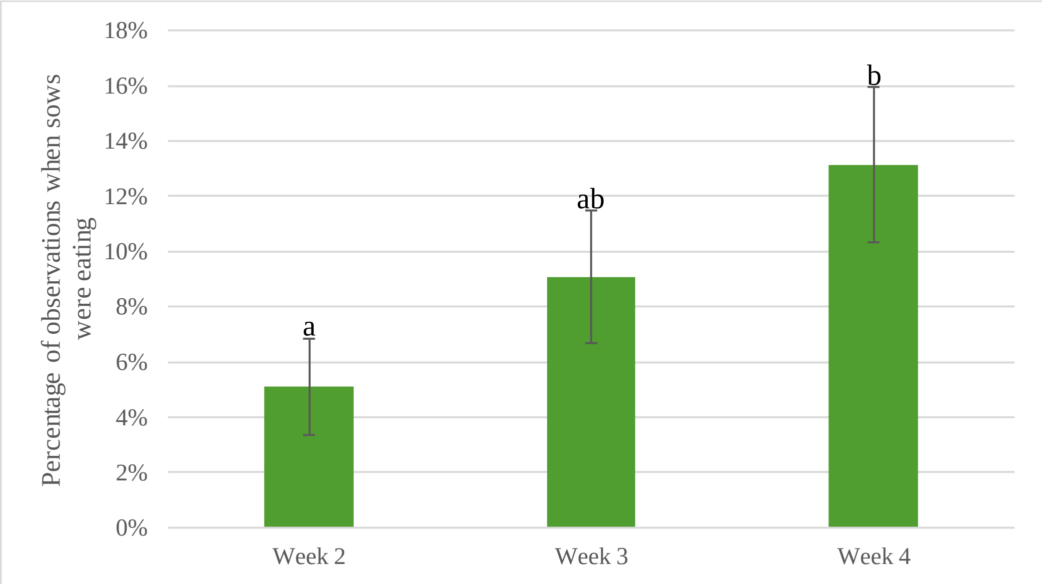
There was a significant difference between weeks in sow *nosing* behaviour (P=0.016, F=4.16) and *eating* behaviour (P=0.03, F=3.53) (graph 7 & 9). Regarding sow *movement*, there was a tendency towards significance between weeks (P=0.055, F=2.93) (graph 8).



Graph 7. Least-square means and standard error for percentage of observation minutes the sows were nosing. Different letters above the bars indicate a statistical pair-wise difference at P<0.05. Six sows in treatment 5 were included in the analysis. N=890 observation minutes



Graph 8. Least-square means and standard error for percentage of observation minutes the sows were moving. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. Six sows in treatment 5 were included in the analysis. N=890 observation minutes

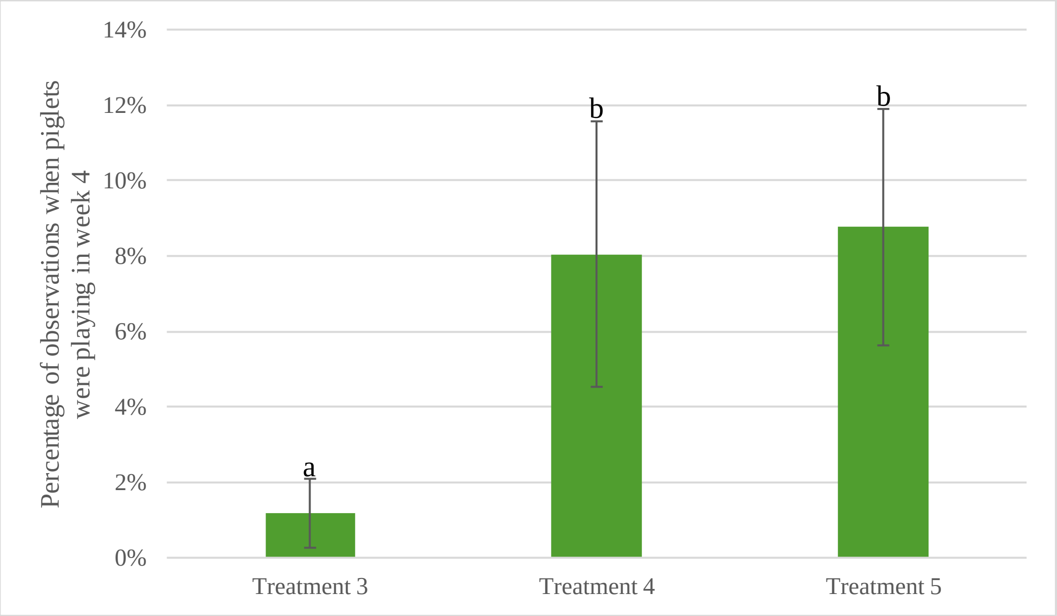


Graph 9. Least-square means and standard error for percentage of observation minutes the sows were eating. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. Six sows in treatment 5 were included in the analysis. N=890 observation minutes

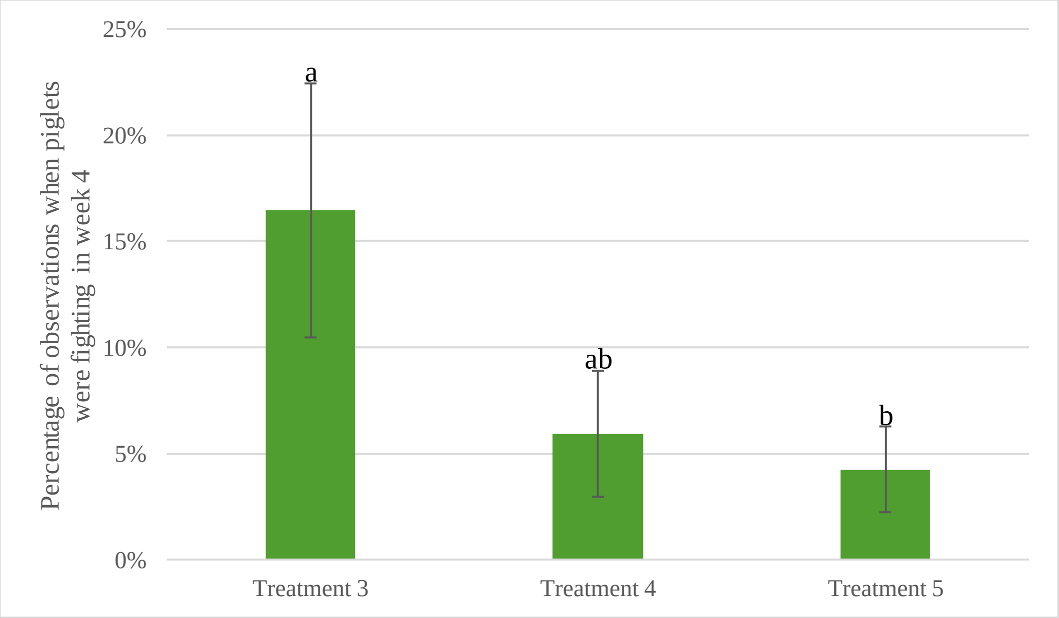
4.1.2.2 Piglet behaviour

Belly nosing showed a statistical difference between treatments in week 5 (P=0.015, F=5.88) (graph 13). In week 4, *fights* (P=0.092, F=2.89), *mounting* (P=0.094, F=2.85), and *play* (P=0.082, F=3.03) showed a tendency towards significant differences between treatments (graph 10, 11 & 12). The least-square means and standard errors are described in the graphs below.

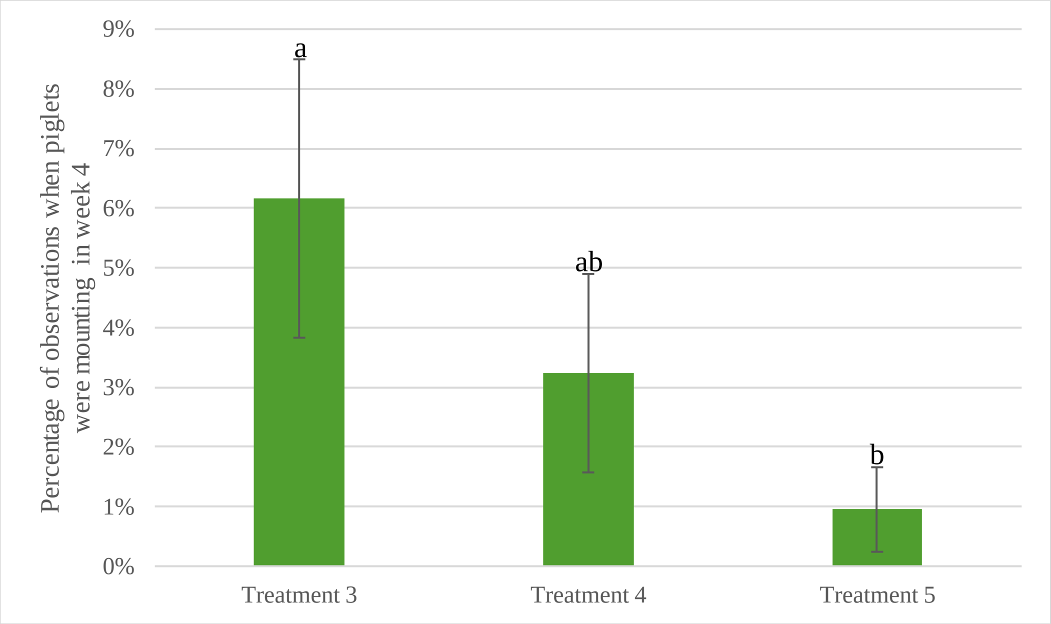
4.1.2.3 Week 4



Graph 10. Least-square means and standard error for percentage of observation minutes the piglets were playing in week 4, after weaning of piglets in treatment 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=2223 observation minutes from 5+5+6 litters.

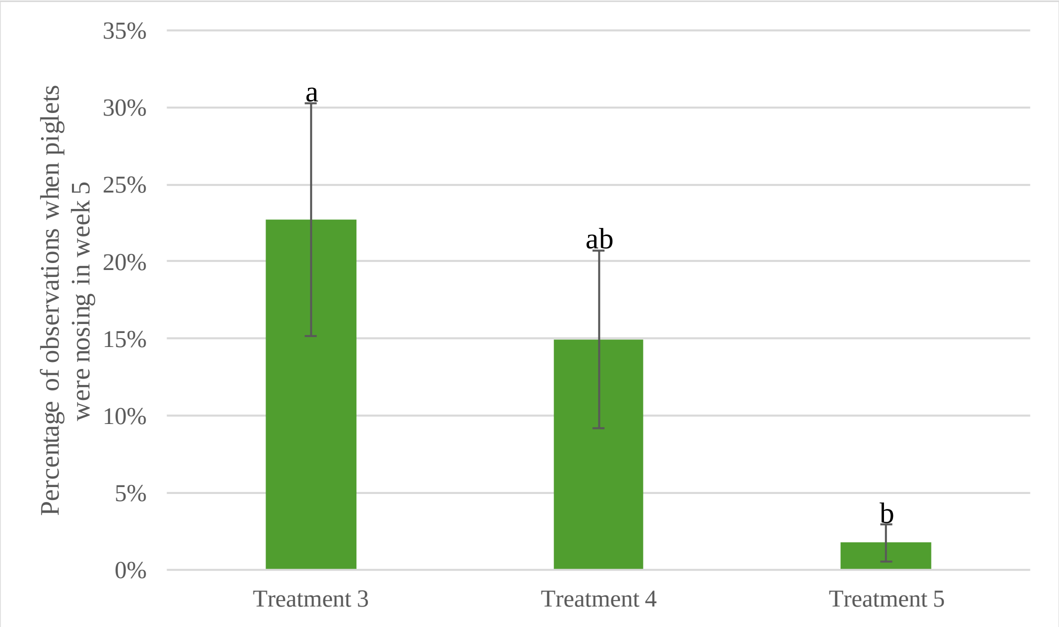


Graph 11. Least-square means and standard error for percentage of observation minutes the piglets were fighting in week 4, after weaning of piglets in treatment 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=2223 observation minutes from 5+5+6 litters.



Graph 12. Least-square means and standard error for percentage of observation minutes the piglets were mounting in week 4, after weaning of piglets in treatment 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=2223 observation minutes in 5+5+6 litters.

4.1.2.4 Week 5



Graph 13. Least-square means and standard error for percentage of observation minutes the piglets were nosing in week 5, after weaning of the piglets in treatment 3 and 4. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=2223 observation minutes from 5+5+6 litters.

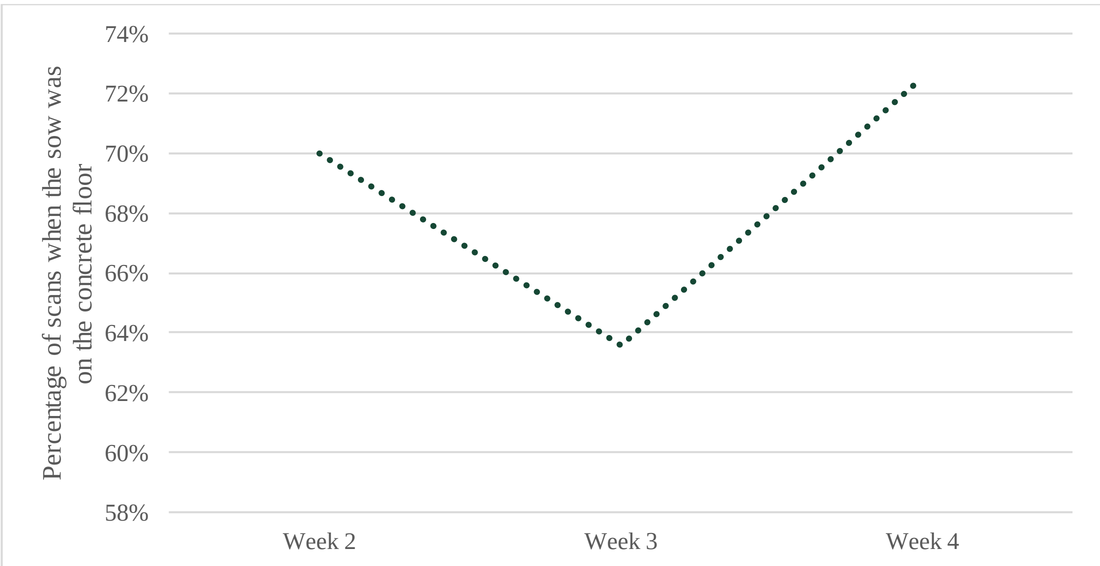
4.2. Scan sampling of sow and piglet behaviour

4.2.1. Descriptive statistics of sow and piglet behaviour

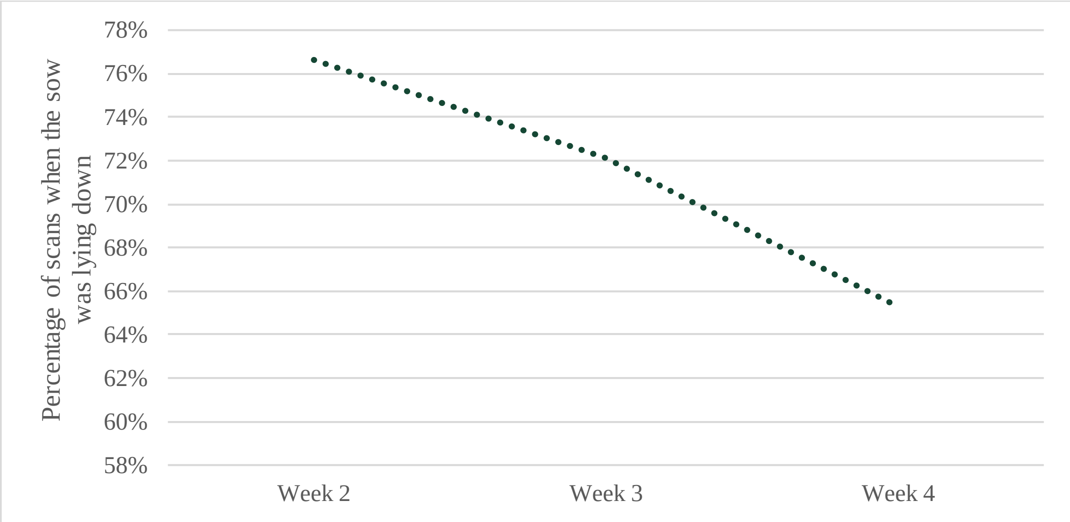
Means and standard deviations (std dev) were estimated for all behaviours to display the frequency of behaviours throughout the recordings (Table 7).

Table 7. Mean percentage of scans the sow spent in different locations in the pen and of studied behaviours during week 2-4. N = sow-week, (2 weeks for sows in treatment 3, 3 weeks for sows in treatment 4 and 4 weeks for sows in treatment 5)

Sow variable	N	Mean (%)	Std Dev (%)
Location in pen			
Concrete	16	63.0	17.5
Slatted floor	16	33.7	18.3
Behaviour			
Lying	16	69.2	17.2
Standing	16	20.8	10.7
Sitting	16	2.8	4.5
Eating	16	9.9	9.3
Drinking	16	2.2	4.3
Furniture	16	5.7	8.3
Floor	16	6.9	7.6
Straw mouth	16	0	0
No activity	16	0.2	1.1
Interaction	16	6.8	7.1



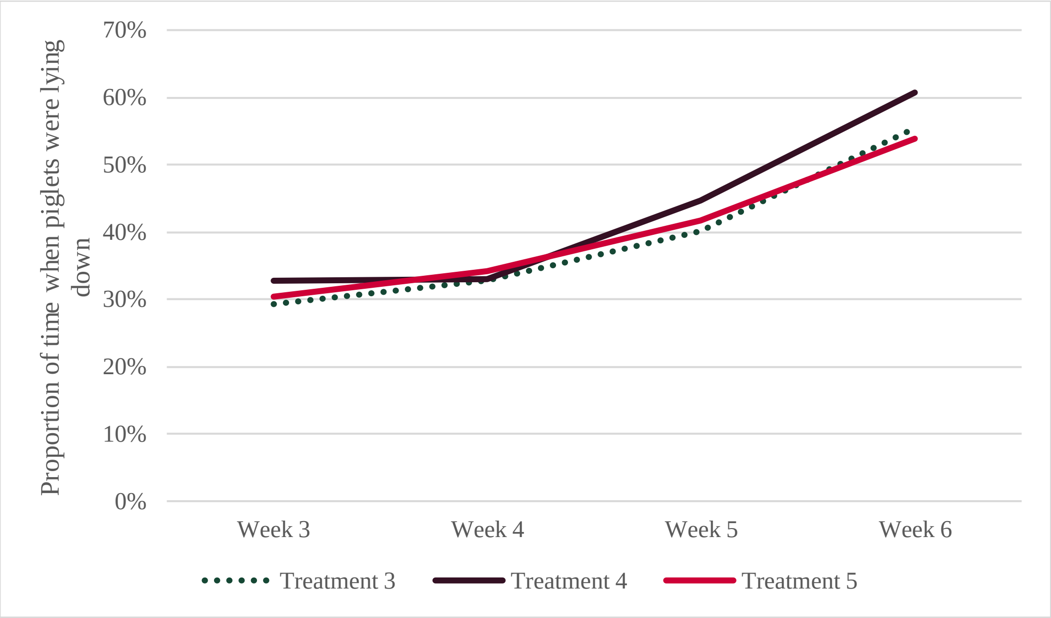
Graph 14. Proportion of scans when the sow was placed on the concrete floor in the pen between weeks 2-4. Six sows in treatment 5 were included in the analysis. N= 16 sow-weeks



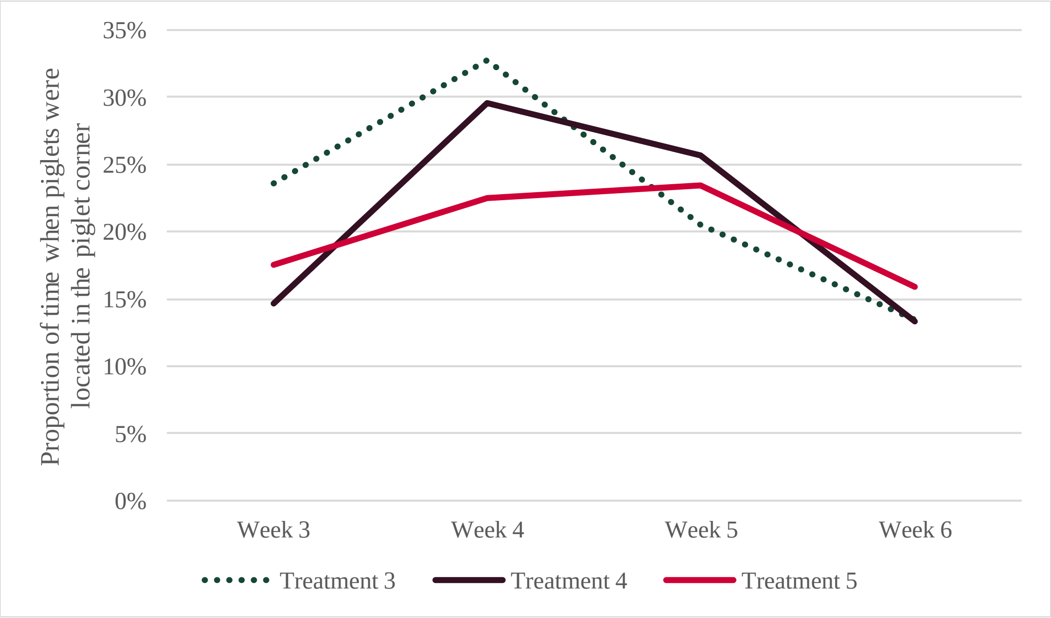
Graph 15. Proportion of scans when the sow was lying down between weeks 2-4. Sows in treatment 5 were included in the analysis. N = 16 sow-weeks

Table 8. Mean percentage of scans per week piglets spent in different locations in the pen and of studied behaviours in 16 litters during week 3-6. N = litter-week

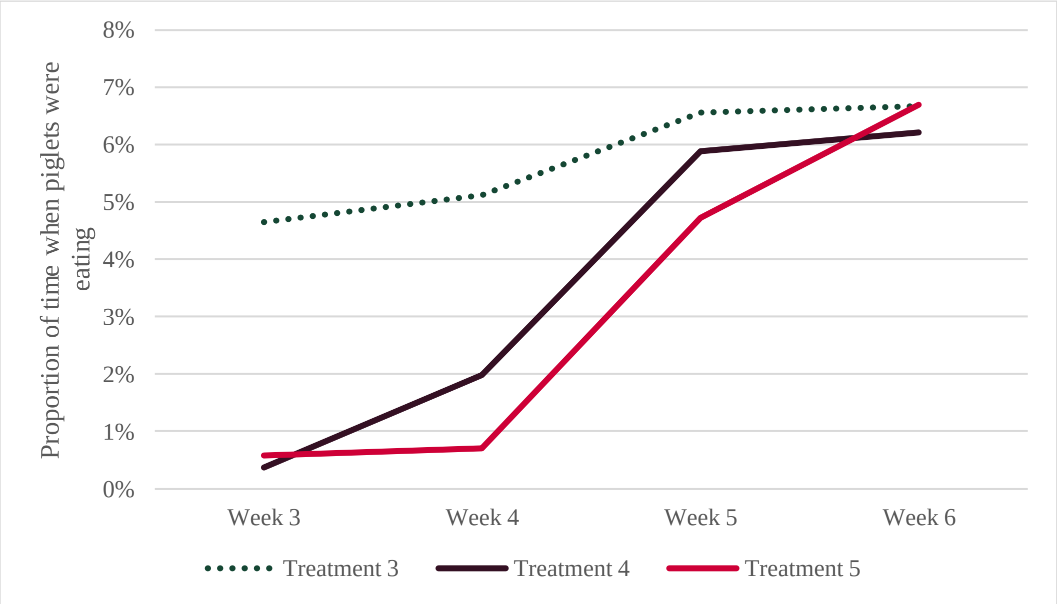
Piglet variable	N	Mean (%)	Std Dev (%)
Location in pen			
Corner	76	19.7	8.0
Slatted	76	14.0	8.1
Concrete	76	48.8	13.7
Behaviour			
Standing	76	25.5	6.2
Sitting	76	2.1	1.6
Lying	76	40.5	13.7
Feed	76	3.4	2.9
Water	76	0.5	0.5
Sow feed trough	76	1.8	1.6



Graph 16. The proportion of scans piglets were lying down showed in a timeline week 3 through week 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 76 litter-weeks



Graph 17. The proportion of scans piglets were in the piglet corner showed in a timeline week 3 through week 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 76 litter-weeks



Graph 18. The proportion of scans piglets were eating showed in a timeline week 3 through week 6. The first results of weaned piglets are presented the week after weaning; treatment 3 in week 4 (5 litters), treatment 4 in week 5 (5 litters), treatment 5 in week 6 (6 litters). N= 76 litter-weeks

4.2.2. Statistical analysis of sow and piglet behaviour

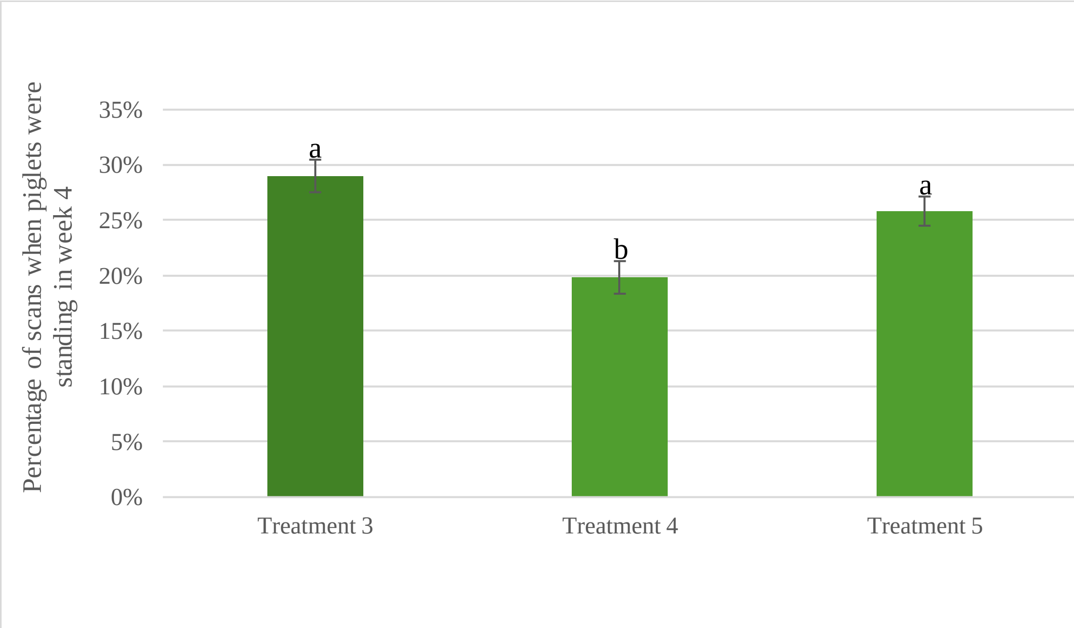
4.2.2.1 Sow behaviour

There were no significant differences in behaviours or locations in pen between weeks for the sow behaviours analysed.

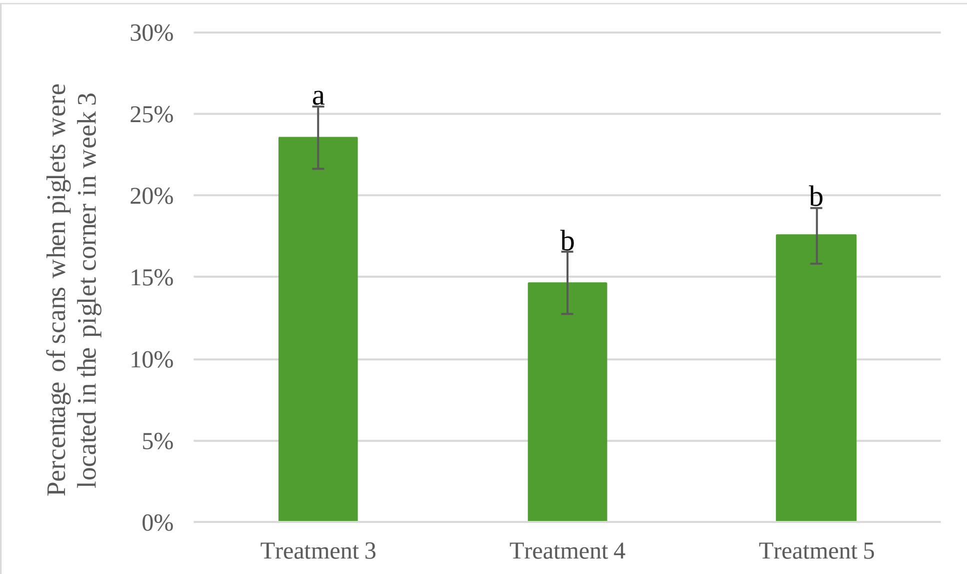
4.2.2.2 Piglet behaviour

There were significant differences between treatments in piglet behaviours *standing* during week 3 (F=10.03, p=0.004) and 4 (F=6.20, p=0.014), as shown in graphs 19 & 22. In week 3, there was a statistical significance between groups in the prevalence of piglets in the *piglet corner* (F=5.70, p = 0.022); see graph 20. At the same time, there was a tendency of significance between groups on the *slatted area* during week 4 (F=3.16, p=0.079). There was also a difference between treatments of whether the piglets were *eating* during week 3 (F=15.08, p = 0.001), week 4 (F=18.60, p = 0.0002) and a tendency of significance in week 5 (F=3.21, p = 0.074) (graph 21, 23 & 24). No other significant differences were found in the statistical analysis behavioural data derived from scan sampling. The least-square means and standard errors are described in the graphs below.

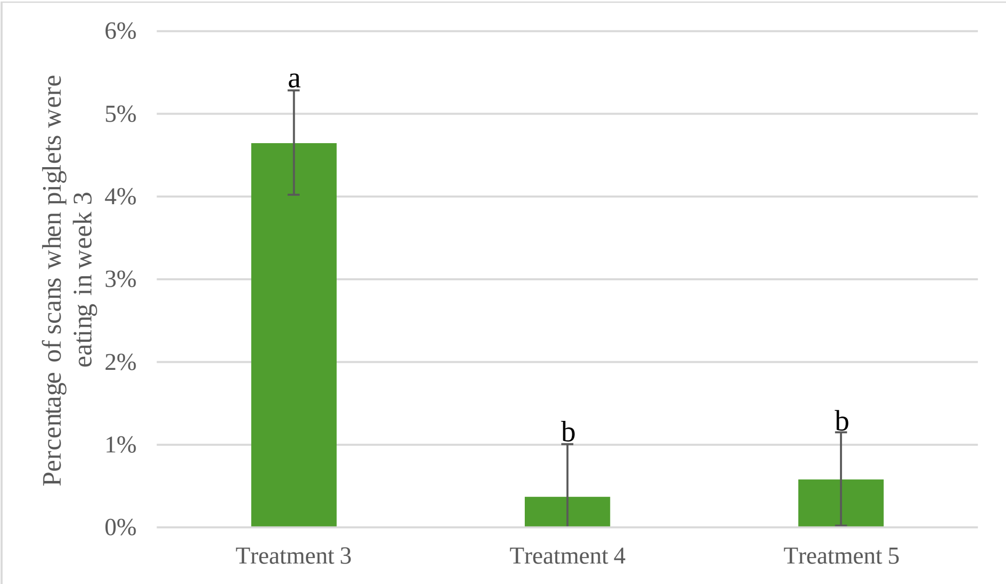
4.2.2.3 Week 3



Graph 19. Least-square means and standard error for percentage of scans when the piglets were standing in week 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks from 5+5+6 litters

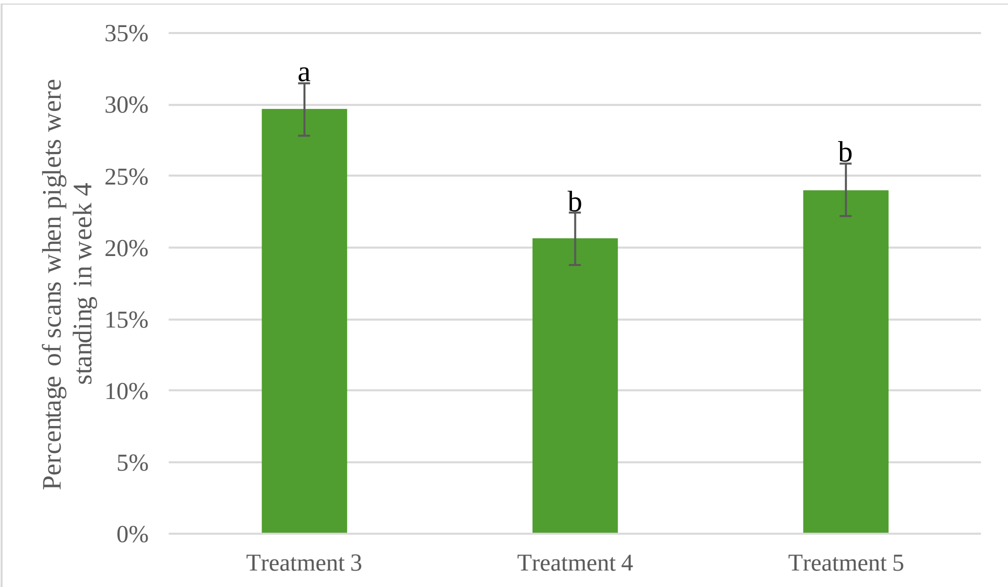


Graph 20. Least-square means and standard error for percentage of scans when the piglets were located in the piglet corner in week 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks from 5+5+6 litters.

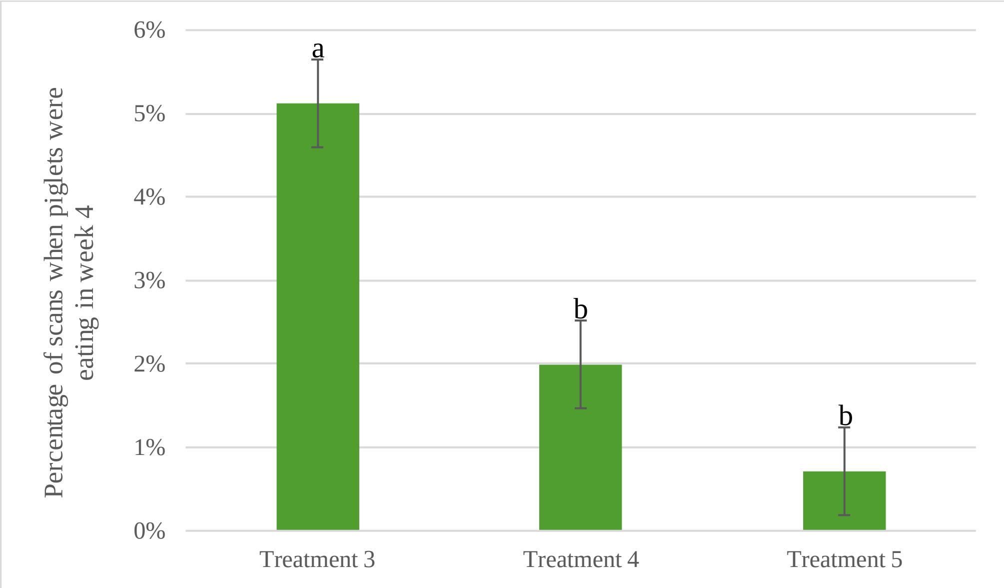


Graph 21. Least-square means and standard error for percentage of scans when the piglets were eating in week 3. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks for 5+5+6 litters.

4.2.2.4 Week 4

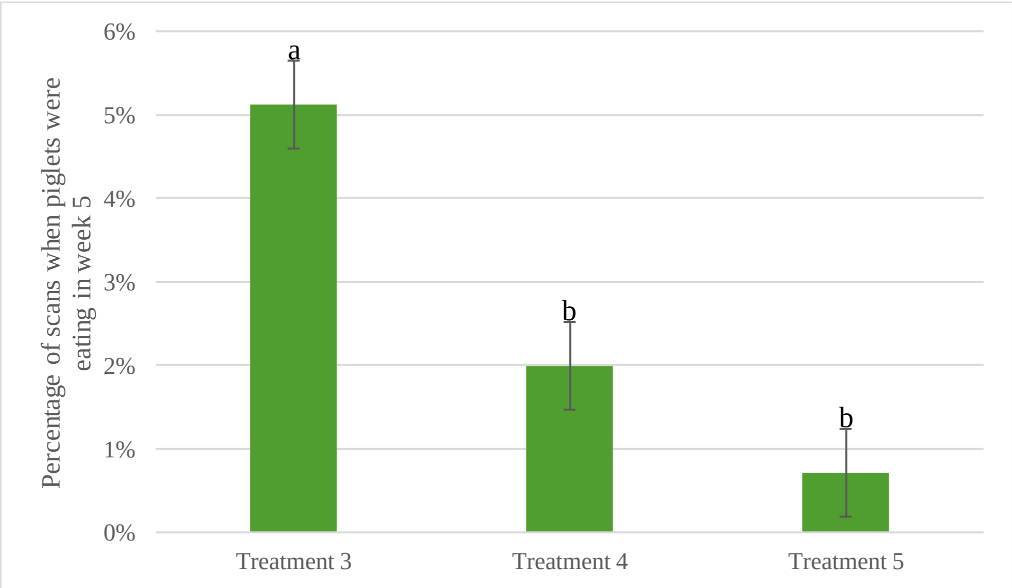


Graph 22. Least-square means and standard error for percentage of scans when the piglets were standing in week 4. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks for 5+5+6 litters.



Graph 23. Least-square means and standard error for percentage of scans when the piglets were eating in week 4. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks for 5+5+6 litters.

4.2.2.5 Week 5

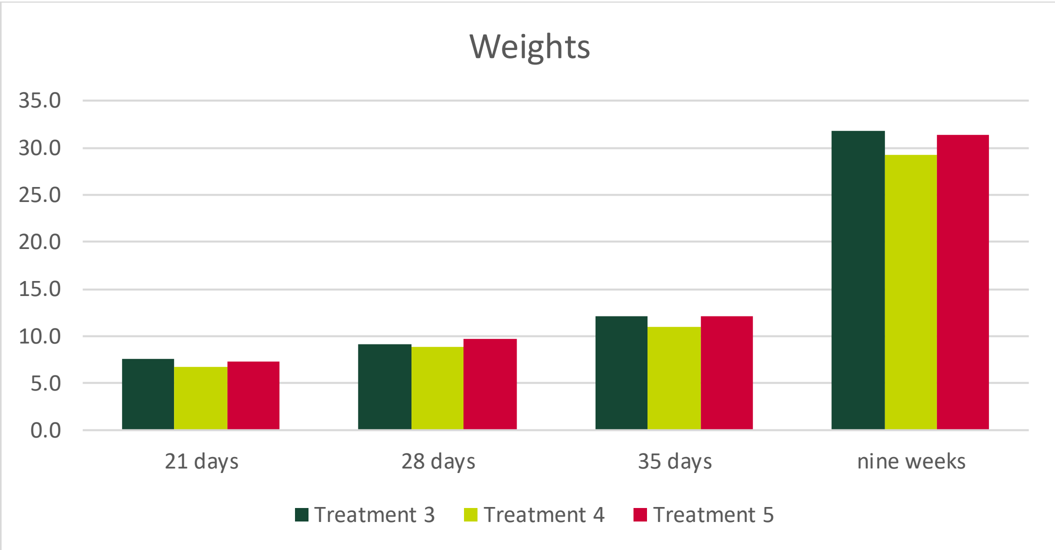


Graph 24. Least-square means and standard error for percentage of scans when the piglets were eating in week 5. Least-square means and standard error. Different letters in the bars indicate a statistical pair-wise difference at P<0.05. N=76 litter-weeks for 5+5+6 litters.

4.3. Physiological parameters

4.3.1. Descriptive statistics of physiological parameters

Mean weights for each treatment and weighing was estimated for piglet weights, sow weights and backfat thickness (graph 25, table 9 & 10). The difference of mean weights and backfat thickness over time was calculated for sow variables (table 9 & 10).



Graph 25. Change of mean piglet weights between treatments from 21 days of age until nine weeks of age, shown in kg. N=16 litters (5+5+6)

Table 9. Mean farrowing weights and weaning weights of sows depending on treatments. Weaning ages differed between treatments, and the time between measurements differed accordingly. Treatment 3 = 7 sows, Treatment 4 = 6 sows, Treatment 5 = 6 sows. N=19 sows

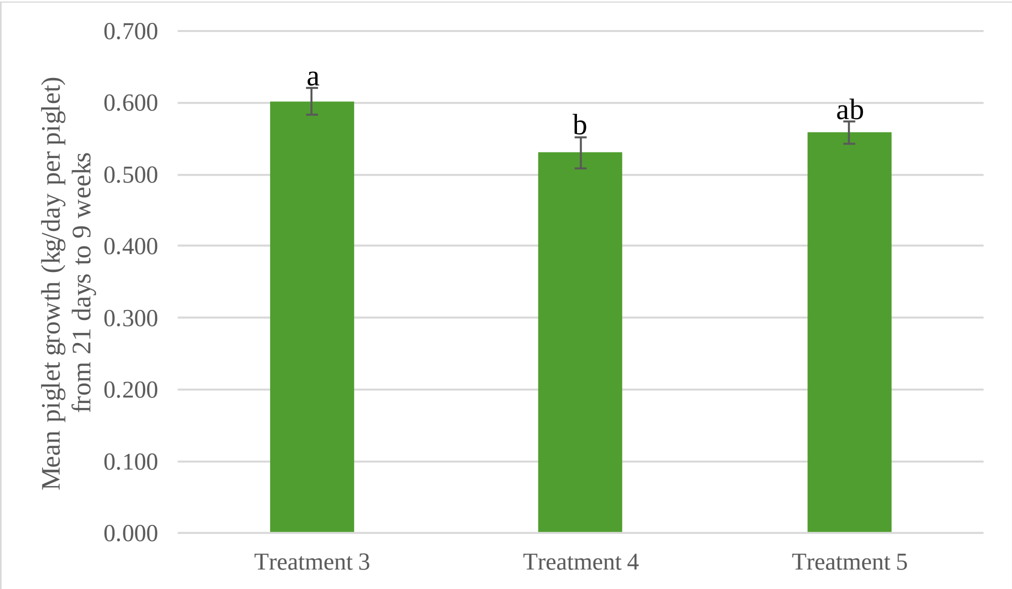
Treatment	Farrowing weight, kg	Weaning weight, kg	Difference, kg
3	274.7	253.7	-21.00
4	267.3	247.2	-20.2
5	271.5	250.7	-20.8

Table 10. Mean farrowing backfat thickness and weaning backfat thickness of sows depending on treatments. Weaning ages differed between treatments, and the time between measurements differed accordingly. Treatment 3 = 7 sows, Treatment 4 = 6 sows, Treatment 5 = 6 sows N=19 sows

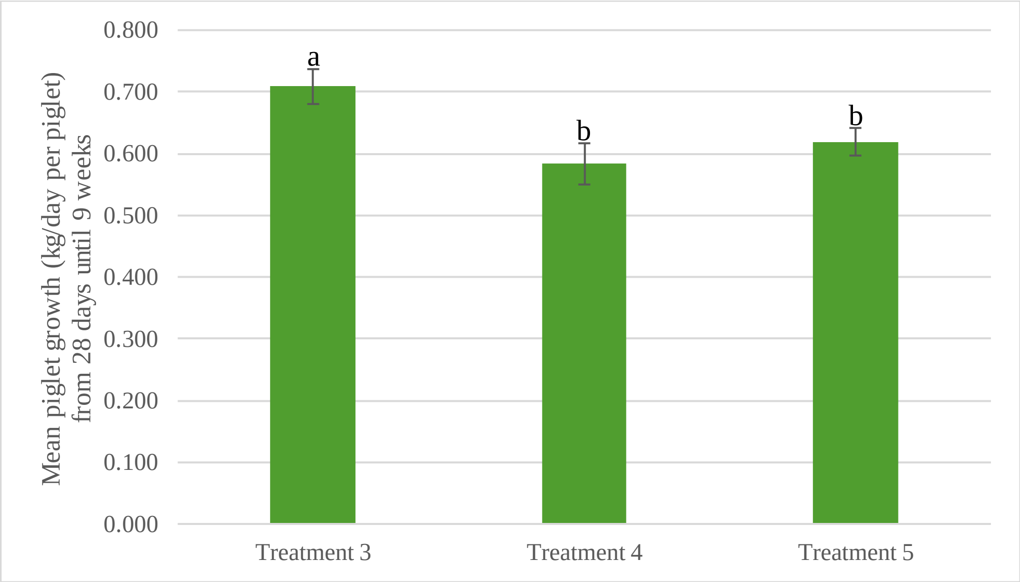
Treatment	Farrowing backfat thickness, mm	Weaning backfat thickness, mm	Difference, mm
3	14.4	11.1	-3.3
4	16.2	11.7	-4.5
5	17.8	12.2	-5.7

4.3.2. Statistical analysis of physiological parameters

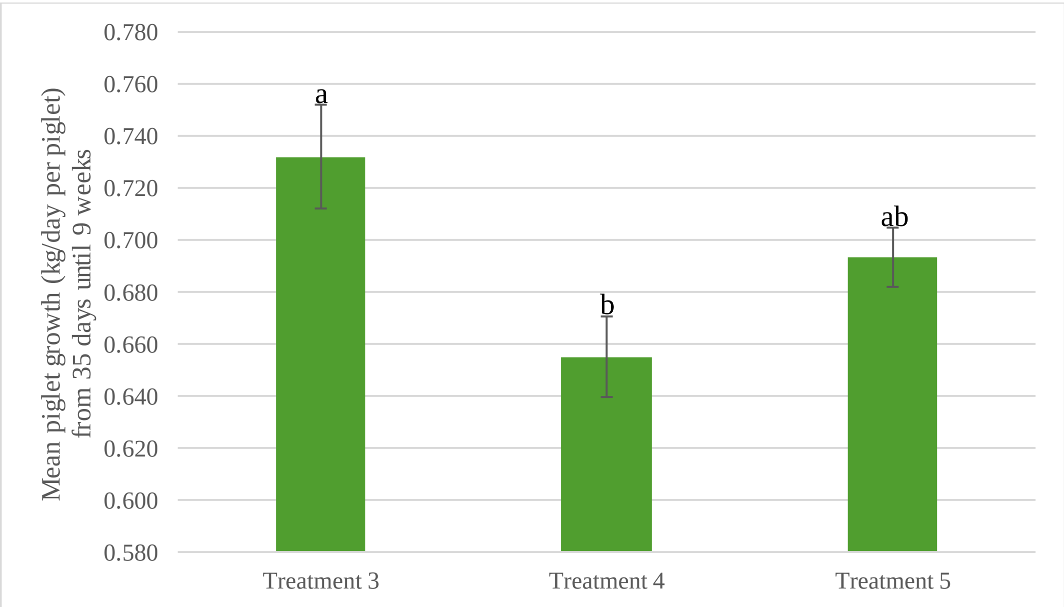
There was an effect of treatment on piglet growth from 21 days of age until 9 weeks of age (p=0.037, F=3.90). There was an effect of treatment on piglet growth from 28 days of age until 9 weeks of age (p=0.034, F=4.85). There was an effect of treatment on piglet growth from 35 days of age until 9 weeks of age (p=0.01, F=7.68). Pair-wise differences and level of significance between treatments are presented in graph 26, 27 & 28. No other piglet growth variables had significant effects of treatments. There was no significant effect of treatment on neither sow weight nor backfat thickness change.



Graph 26. Pair-wise comparisons of piglet growth (least-square means; kg/day per piglet) from day 21 until 9 weeks. Different letters indicate pair-wise differences of P<0.05. N=16 litters (5+5+6)



Graph 27. Pair-wise comparisons of piglet growth (least–square means) during day 28 – 9 weeks. Different letters in the bars indicate a statistical difference at P<0.05. N=16 litters (5+5+6)



Graph 28. Pair-wise comparisons of piglet growth (least-square means) during day 35 – 9 weeks. Different letters in the bars indicate a statistical difference at P<0.05. N=16 litters (5+5+6)

5. Discussion

This master thesis aimed to investigate the effects of weaning age on behaviour, weight, and body condition on sows and its effects on piglet behaviour and weight gain. This thesis also aimed to investigate whether these effects may cause possible conflicts between the needs of the sow and piglets from those results. Behavioural recordings were made in two sets, both in the farrowing pen: Variables concerning body position and location in pen was recorded by scan sampling, and interactions between animals were recorded through continuous recording. Physiological parameters were collected throughout the study with the standard routines of stable management.

5.1. Behavioural observations

5.2. Sow behaviour

The sows were *nosing* the piglets less between week 2 and 3 (graph 1). However, there was a slight increase in *nosing* behaviour between weeks 3 and 4. Due to low numbers of sows and occurrences, the differences cannot be used to draw definite conclusions on the effects that the age of the piglets has on nose contact between the sow and piglets. Even though the results are inconclusive, the decline of nosing behaviour over time may indicate that the sow avoids close contact with the piglets. Since natural weaning includes physical distance, the avoidance of close contact can indicate an initiated weaning procedure. There were no significant differences between different weeks considering sow behaviours and location in pen. However, lying behaviour decreased over time, and the low number of sows used in the analysis may be why there were no significant results in the analysis (graph 2). As an extension to the ideas on why *nosing* decreased over time, the decrease of lying behaviour, and thereby increase of activity, can indicate two things. First, it may indicate that nursing behaviour has decreased since the sow is lying down during nursing. Second, it may be another indicator that the sow avoids close contact with the piglets by standing and, therefore, avoiding piglets close to the snout and climbing on the back. It is relevant to consider that it could result from the piglets growing and becoming more active. Therefore, the decrease of lying behaviour could result from an experienced lack of space in the pen and not directly connected with the process of weaning. The results of *nursing* were inconclusive. The main issue with the data was the lack of frequency of the data collection. Since nursing occurs regularly (Keeling & Jensen 2009) and over a more extended period, the short and limited number of continuous recordings made the results inconclusive and unfit to process further in the analysis. To further investigate how weaning age affects nursing behaviour, it would be necessary to observe for a more extended and coherent period. It would also be used to register whether the weaning age affects if the sow or the piglets' initiates and terminates nursing.

Further research should investigate how sow behaviour post-weaning is affected by different weaning ages. The current study investigated how the behaviour of sows change when the weaning age is increased. However, the results of this study do not provide answers to how sow behaviour changes after weaning have occurred since their behaviour was not registered in this period.

5.3. Piglet behaviour

Regarding location in pen, the piglets in treatment 3 spent significantly more time in the piglet corner than those in treatment 4 and 5 (graph 20). The definition of *piglet corner* was different depending on whether the wall with pop holes was removed or not (i.e. before and after weaning), and the definition itself may be why there is a difference in occurrence. However, the difference may still indicate that piglets spent more time close to each other after weaning when weaning occurs before four weeks of age. *Play* did not show much difference between the treatment groups in general (table 3). However, in week 4, there were statistically significant differences between Treatment 3 and the other treatments (graph 10). Since play behaviour can indicate positive emotions (Reimert *et al.* 2013), the decrease of such in the group that has been weaned earlier than the other groups may indicate that these piglets experience less positive emotions. This study did not show significant differences between treatments when the piglets were older, indicating that, during this experiment, the piglets decrease in play behaviour over time no matter the accessibility of the sow. However, the results show a significant difference in play behaviour early on after weaning when the piglets are no older than 21 days, compared to piglets weaned later. Although the difference between treatment 3 and 4 could not be proven statistically, the trend of more *fights* occurring among the piglets weaned on day 21 was significant between treatment 3 and 5 on week 4 (graph 11). Since fights can be a result of social reconstructions such as the mixing of piglet groups (Colson *et al.* 2012), there is a possibility that the difference between treatments is an effect of the social reconstruction following the removal of the sow. *Mounting* behaviour seemed to occur more often in all the treatments right after weaning (table 5). There was a significant difference between treatment 3 and 5 in weeks 4 (table 12) and 5 (table 13). Fighting and mounting behaviour both affect pain levels and the welfare of the piglets negatively (Rydhmer *et al.* 2007). Thereby, these results indicate that, even two weeks after weaning, the piglets weaned 21 days after farrowing display behaviours that negatively affect their pen mates to a more considerable extent than later-weaned piglets.

Treatment had a significant effect on *belly nosing*, specifically on the pair-wise comparison of treatment 3 and 4 as well as treatment 3 and 5 in week 5 (graph 13). There seems to be a gradual increase in *belly nosing* with decreased weaning age (graph 6). These results align with earlier studies on early weanings' effect on belly nosing occurrences (Algers 1984). No behaviours had significant differences between treatments during the sixth week. There are a few different factors that could be the explanation of these results. It may be that the study was too small to provide the statistical evidence to prove any differences between treatments, but there were still some descriptive results that are of relevance. Those indicate that piglets in treatment 5 were *fighting* (graph 4) and *mounting* (graph 5) slightly more than piglets in the other treatments in week 6. Another result worth noting is that *belly nosing* occurs almost half as much in treatment 5 than the other treatments in week 6 but is in a steep increase compared with week 5 (graph 6). It would, therefore, be interesting to see the difference between treatments in the seventh week to see whether the behaviour decrease in occurrence similarly as with the other treatments. The results from week 7 may have provided a picture of whether belly nosing ended up in the same occurrence in all treatments later. The Swedish legislation states that abnormal behaviours may only occur uncommonly if the rules of weaning 10 % of piglets at 21 days of age are to be followed (SJVFS 2019:20 Saknr L106 3 Kap. 2 §). It is unclear, though, how to measure this and where to draw the limit. This thesis found that belly nosing occurred at a statistically higher rate in piglets weaned at 21 days of age than those weaned at 28 and 35 days of age. With the background of these results as well as those of Algers (1984), Gonyou *et al.* (1998), Weary *et al.* (1999), and Orgeur *et al.(* 2001), it is evident that decreased weaning ages increase the risk of abnormal behavioural traits.

One aspect that may be considered when discussing the effects of early weaning on the piglets is that emotions can spread throughout a group of pigs (Reimert *et al.* 2013). Suppose one or a few piglets in a group are more prone to experience negative emotions related to social deprivation from weaning. In that case, this may also affect the other piglets in the same pen (Reimert *et al.* 2013). When investigating this, the effects between pens were not investigated, and it is not clear how this effect impacts pigs sharing the same unit (Reimert *et al. 2013)*. Depending on how this contagion of emotion spreads, say if squeals and screams influence surrounding pigs without visual stimuli, this could impact other groups of piglets within the same unit. The current Swedish legislation states that 10 % of a herd may be weaned up to 7 days earlier than the rest of the herd, making this an important aspect (SJVFS 2019:20 Saknr L106 3 Kap. 2 §). Reimert *et al.* (2017) found that there is emotional contagion among pen mates. However, they did not find definite answers about which cues impacted the other pen mates; olfactory, visual, or oral stimuli. Goumon & Špinka (2016) found that emotional contagion increases if the pig observing another distressed pig has had the same experience. With these studies in mind, there is a clear need for further research to comprehend the emotional effects on piglets within and surrounding litters that are weaned at an earlier age. Another aspect that should also be considered with emotional contagion is whether the sow's state affects her piglets negatively if she is distressed. If, for example, a litter is weaned later and the load on the sow increases with time and age of the piglets, could it be that this also affects her piglets negatively by emotional contagion? Since pigs are group-living animals, it may also be relevant to consider whether piglets' distress due to early weaning also affects other sows in the herd, who have not yet been weaned from their piglets.

The pop hole between two pens opened during the third week of observations in a treatment 3 litter (figure 1). At this point, the piglets were already weaned and entered another pen with a sow and other piglets. Therefore, these piglets were exposed to a sow for around 12 hours, four days after weaning. The observations were paused until the staff returned the piglets to their original pen.

5.4. Physiological parameters

Although there were no significant differences between treatments, sows in treatment 5 had more backfat loss after weaning than sows in treatment 3 and 4 (table 10). However, sows in treatment 5 had more backfat in the beginning of the study. Since there was a low number of sows in the study, it is difficult to distinguish whether the increased loss of backfat with later weaning was connected with these sows' backfat thickness at the beginning of the study or due to the increased weaning age. Sow weights did not differ between treatments (table 9). Considering the results of this study, as well as those in Van Der Meulen (*et al.* 2010), Wallgren & Gunnarsson (2015) and the analysis from (Berg *et al.* 2020), the overall impression is that the decrease of sow backfat due to increased weaning age is not reflected on weight loss. To further investigate the effects of different weaning age on sow physiology, it would be relevant to compare if it affects teat health, as larger piglets staying for a more extended time could affect teat injuries on the sow.

The significant differences between treatments regarding piglets were piglet growth between day 21 to 9 weeks (graph 26), day 28 to 9 weeks (graph 27) and day 35 to 9 weeks (graph 28). In all three of these comparisons, piglets in treatment 3 increased more in weight than the other piglets. Since the variations in those results are relatively large, and the number of piglets and sows in each treatment is relatively low, a more extensive study would likely provide a clearer image of how weaning age affect piglet growth in these conditions. However, after pigs and other mammals have experienced undernutrition, a mechanism called compensatory growth is induced (Gädeken *et al.* 1980). If the piglets experience nutritional deprivation that inhibits their growth, they will compensate by increasing the growth rate later when they no longer experience undernutrition (Gädeken *et al.* 1980). Whether that is the case in this study due to early separation from the sow is hard to say. Generally, the increased growth only compensates for the growth it has lost. Therefore, it does not provide a reasonable explanation as to why the piglets in treatment 3 are larger both by size and have a higher growth rate than the piglets in other treatments. It could be that the piglets weaned earlier eat enough solid food to gain more energy intake than piglets who still nurse. A possible reason for this would be that the piglets spend more time and energy foraging (massaging the teats) than the weaned piglets that eat directly from the automatic feeder. In this study, one litter in treatment 3 developed diarrhoea. The low incidence of diarrhoea among the piglets can result from well-planned creep feeding (Hampson & Smith 1986). Other possibilities are that the infection control measures for SPF facilities are sufficient to sustain good gut health in early-weaned piglets or that the different breeds used in the study affect how the piglets react to solid food. A larger study could investigate the effects of different breeds. However, this was not taken into account due to the size of this thesis.

The observer noted that when one or two piglets were eating from the feed trough, other piglets would often stand next to the feed trough. Sometimes, piglets would mount the piglet eating from the feed trough. These behaviours would be followed by a change of piglet eating from the trough or fights between the piglets. It would be of interest to further investigate whether this seeming lack of feed space in the farrowing pen affected the weight gain in some piglets and if the weaning age matters when it comes to the occurrence of disturbed food intakes.

5.5. Potential conflicts between the needs of the sow and piglets

One of the aims of this thesis was to investigate possible conflicts between the needs of the sow and piglets related to weaning age. Piglets in all treatments began belly nosing immediately after weaning, and earlier weaning also resulted in a higher occurrence of abnormal behaviour (graph 6). They would also fight (graph 4) and mount (graph 5) more with earlier weaning.

In contrast, the sows were more active with time (graph 2) and had somewhat less snout contact with the piglets as the age of the piglets increased (graph 7). These results imply that the sows may have wanted more distance to the piglets with increased weaning age. Moreover, they lost more backfat with increased weaning age (table 19). Therefore, it cannot be ruled out that piglets need to stay with the sow for a more extended period to develop normal behavioural repertoires. Meanwhile, increased weaning age affected the sows negatively with less rest and loss of backfat. How different weaning ages affected the behaviour of the sows after weaning was not studied in this thesis. Further research would be needed to understand better the relationship between the needs of the sow and piglets depending on weaning age.

5.6. Methodology

The farm in which the study was conducted had some differences in routines compared to most conventional Swedish farms. The piglets were not mixed with piglets from other pens, they stayed in the same pen after weaning, and the automatic feeders ensured an even distribution of feed throughout the day. These differences in management may have had effects on behaviour as well as growth in piglets after weaning.

5.6.1. Video analysis of sow and piglet behaviour

Ingram & Dauncey (1985) found that even though the wild boars are mainly nocturnal, the domesticated pig has adapted to a diurnal rhythm, meaning they are active during daylight. The same study concludes that young pigs seem to have a weaker circadian rhythm than adult animals of other species such as rodents and birds. The study suggested that this has been a suitable characteristic for domestication because they could be adapted to the circadian rhythm of humans. A recent study compared wild boars' circadian rhythm in human-dominated landscapes with wild boars in no-hunting zones (Johann *et al*. 2020). The said study found that the wild boars in no-hunting zones spent more time being active in daylight. It was, therefore, in the current project premised that the activity level of piglets would be lower during night-time. Due to this background, the scan samplings were limited to daytime (7:00 – 20.00) to fit as much relevant data sampling as possible to the project's limited timeline. Timing for the continuous observations (9:00, 13:00, 17:00) was determined considering the on-site routines described by the staff. Any treatments (e.g., iron injections, weighing) were made approximately around 10:00 – 12:00. Therefore, abruptions to the observations were avoided while giving the pigs some time to acclimatise after any potential treatment.

The videos were recorded using dome cameras with a 1 FPS rate. The FPS rate made it easier to work with the material since the videos were relatively small. Therefore, it did not strain the processor as much as more extensive video material would. The cameras made it possible to view the entire pen except for the piglet corner in which the roof was in the way of the view. Therefore, most *no vision* of location in pen was a result of piglets being in the corner. There may also have been incidences where the sow was standing up and thereby blocking the view. The farrowing pens were mirrored within the units, and the cameras were placed at the same angle. Therefore, some observations had little insight into the piglet corner. The cameras' different angles affected the perception of where most of the body was placed in the farrowing pen and the number of *no vision* registrations since they were slightly more visible in those piglet corners. An estimation of how large proportions of the piglets' bodies would have been visible from the pens with less insight was made on borderline cases registered as either on the concrete floor or the piglet corner. The low FPS rate, moisture on the camera lens and overall video quality were the main issues for observations. These circumstances made for a rough estimation of behaviours where discreet or short-lasting behaviours were missed. Another problem with the low framerate was that the dynamic of behaviours was difficult to distinguish. For example, whether piglets were jumping out of fright or play could be challenging to differentiate. Future studies could further investigate how more discrete behaviours, such as ear- and tail movement or who initiates play and fights, are affected by different weaning ages. With more generalised measurements of behaviours as in the current study, there is a risk that essential parts of interactions between the animals are missed. The differences in behaviour and location in pen were easier to spot with the increasing size of the piglets; they became less blurred with age. As a result, there are fewer records of whether the piglets were, e.g., standing or sitting in the first weeks because it was difficult to see. Therefore, more data described where the piglets were placed in the pen than descriptions of the piglets' body posture. Granted that cameras with higher FPS rates would provide a more detailed picture of the animals' behaviours, the FPS rates would result in heavier files that would be more difficult for computers to process. Moreover, cameras in several angles would incite more work for the observer and exceed this project's timeline. The chosen methodology for recording the behaviours in this project is seemingly the one that results in as much information gathering as possible, as efficiently and manageably as possible, with the conditions given.

As discussed above, the methodology of this study had its clear pros and cons. There are several other ways in which this study could have been carried out. If the observations had been on-site with a live observer, there would have been less need for technical solutions and made it easier to spot the small behaviours and give more descriptive imagery of the behaviours. However, live observations do have negative aspects that need to be considered. For example, the consequence of not pausing and rewinding could be that several behaviours would be missed. Missing those registrations could be due to distractions, technical difficulties with timers, and human error; it is challenging to constantly stay wary of one's surroundings. Therefore, the risk of observational errors is impending. Considering that all observations contained at least ten animals to be observed simultaneously, the setbacks of not pausing and rewinding would be too significant. Besides, there is an apparent benefit of speeding up videos to save time while the animals are inactive and avoiding the risk of affecting the animals' behaviours due to an unknown person's presence.

5.6.2. Aspects of welfare and sustainability

The data collection was conducted on pigs kept in the usual farrowing pens used in the facility. From a research animal welfare perspective, the only thing that differed from normal circumstances was that the sows in treatment 5 stayed in the farrowing pen for a week longer than usual. Because the piglets grow at a fast rate, there may have been a risk that the sow and piglets experienced less space than regularly and may, therefore, have had fewer opportunities to keep distance from their pen mates. However, weaning does not always occur on the first possible day, so this should not be that much greater than the effects of standard weaning procedures when considering space. Regarding the setup for behavioural registrations, all cameras were installed before the sows moved into the farrowing pen and would not affect the animals in the study as they were installed in the ceiling. All behavioural observations were done with recorded videos and did, therefore, not affect the animals. The central welfare aspect to be considered in this study was the behavioural effects of different weaning ages. Since there were effects on behaviour, changes in body conditions and weights, the animals may have experienced stress directly linked to the study itself. All physiological examinations were conducted according to the facilities' routines. These experiments are necessary to gain more knowledge on the welfare effects of different weaning ages under Swedish production conditions. Ideally, more knowledge in this field may lead to national legislation that better reflects the needs of pigs in Sweden. The benefit of this type of small study is that the reduced number of animals included also reduce the overall impact that the study has on animal welfare. In a larger perspective, improved animal welfare increases immune-competence in the animals (Keeling *et al.* 2019). It decreases the use of antimicrobial medicine and, therefore, contributes to reaching the UN sustainable development goals (Keeling *et al.* 2019).

6. Conclusion

This study was conducted in an environment similar to the Swedish pig production environment with individual loose-house farrowing pens and investigated the effects of different weaning ages on sow and piglet behaviour. The results of this study indicate that piglets weaned at 21 days of age spend more time standing up, eating solid food, fighting, and mounting between weeks 3 and 5 than piglets weaned at 35 days of age. Furthermore, they were belly nosing more between weeks 4 and 6. Piglets weaned at 28 days of age were belly nosing more in weeks 5 and 6 than those weaned at 35 days of age. Piglets weaned at 21 days of age had a significantly higher growth rate between 28 days and 9 weeks of age than piglets weaned on days 28 and 35.

Regarding the sows, there were no statistically significant results of behaviour, weight or backfat thickness. However, the sows that were weaned from their piglets on day 35 had 0.5 mm less backfat than those weaned on day 28 and 1.1 mm less backfat than those weaned on day 21. The sows spent less time having snout contact with the piglets and laid down less the longer they stayed with the piglets.

This thesis found potential conflicts between the needs of the sows and piglets when developing regulations on the weaning age of pigs. The piglets developed abnormal behavioural traits when the weaning age was abbreviated and increased fighting- and mounting behaviour. Decreased weaning age also resulted in less play behaviour. Meanwhile, sows had less backfat with increasing weaning age. Moreover, the decrease of snout contacts with the piglets and increase of standing behaviour could indicate that the sows wanted to distance themselves from the piglets as they grew. Because of the low number of sows and piglets, further investigation is necessary to find whether these findings can be proven statistically as a whole and reflect greater populations.

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